Viability Criteria for Application to Interior Columbia Basin Salmonid ESUs

Review Draft
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Interior Columbia Basin Technical Recovery Team

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Background

One of the main tasks assigned to Technical Recovery Teams (TRTs) is the establishment of biological viability criteria for application to Evolutionarily Significant Units (ESUs) of salmon and steelhead listed under the Endangered Species Act[1]. A viable ESU is self-sustaining in nature, not only numerically persistent over time, but also is functional in both the ecological and evolutionary states (McElhany et al., 2000, ISAB 2005). Biological viability criteria are quantitative metrics that describe ESU characteristics associated with a low risk of extinction for the foreseeable future. These biological viability criteria are intended to inform long-term regional recovery planning efforts, including the establishment of delisting criteria. The Interior Columbia Basin Technical Recovery Team (ICTRT) developed a set of viability criteria and guidelines specific for Interior Columbia Basin listed ESUs; those viability criteria are described in this paper.

Our ESU level viability criteria consider the appropriate distribution and characteristics of component populations in order to maintain the ESU in the face of long-term ecological and evolutionary processes. The viability criteria were based on guidelines in the NOAA Technical Memorandum *Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units* (McElhany et al. 2000), the results of previous applications (Puget Sound TRT, 2004 and Lower Columbia/Willamette TRT, 2003 & 2006) and a review of specific information available relative to listed Interior Columbia ESU populations. The population level viability guidelines provided in McElhany et al. (2000) are organized around four major parameters: abundance, productivity, spatial structure and diversity. Our population level viability criteria are designed to address, in combination, all four of these key parameters. Since we defined our ESU level viability criteria in terms of the viability of component populations, we were able to relate ESU viability directly to the primary drivers of evolutionary and ecological functionality.

The Interior Columbia Technical Recovery Team

The ICTRT is one of a series of Technical Recovery Teams established by the National Marine Fisheries Service (NOAA Fisheries) to provide scientific input into regional recovery planning efforts for listed salmon and steelhead. The TRTs are chaired by scientists from Northwest Fisheries Science Center or the Southwest Fisheries Science Center and include experts in population dynamics, conservation biology, ecology and other disciplines relevant to recovery planning. TRT members include scientists from federal and state agencies, tribal resource divisions, academia, and private consultants.

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[1] NMFS has recently delineated steelhead only distinct population segments (DPS) for West Coast steelhead (71 FR 834). In this report we use the generic term ESU to refer a steelhead DPS.

Applications of Viability Criteria

The biological viability criteria described in this report were explicitly developed to inform long-term regional recovery planning efforts and delisting criteria. Given that intent, we worked to express the criteria in objective, relatively specific, and measurable metrics. The quantitative specificity of the criteria gives conservation planners a clear picture of the attributes of viable populations, MPGs and ESUs, while providing a level of transparency that facilitates critical review and future refinements. However, we recognize that there are local circumstances that may make the criteria less applicable to particular populations and that there is uncertainty in both the data and the criteria themselves. For this reason, we have left some room for interpretation or modification of the criteria when well-documented and justified circumstances exist.

The Endangered Species Act (ESA) requires that recovery plans for listed species contain "measurable and objective criteria" that when met would result in the removal of the species from the endangered species list. To be removed from the list, a species must no longer be in danger of or threatened with extinction. Court rulings and NMFS policy indicate that delisting criteria must include both biological criteria and listing factor criteria that address the threats to a species (i.e., the listing factors in ESA section 4[a][1]). The viability criteria relate most directly to the biological delisting criteria; however, they are not synonymous. NMFS establishes delisting criteria based on both science and policy considerations. For instance, science can identify the best metrics for assessing extinction risk and thresholds of those metrics associated with a given level of risk, but setting the acceptable level of risk for purposes of the ESA is a policy decision.

The ICTRT criteria were developed with explicit recognition that the ultimate choice of an acceptable risk level in recovery planning is a policy choice. The ICTRT population level viability criteria are expressed relative to an acceptable risk level of a 5% probability of extinction in a 100-year period. This level of risk is consistent with VSP guidelines (McElhany et al., 2000), the conservation literature (e.g., NRC, 1995), and previous policy guidance that biological objectives based on a 5% (or less) risk of extinction over a 100 year period provide adequate benchmarks for use in assessing recovery.(NMFS, 2005). In addition, we recognize that recovery plans may use these basic biological criteria as a path for setting broad-sense recovery goals for an ESU that reflect policy needs to address additional societal values such as providing for fully functioning ecosystems, fishing opportunities and opportunities for the public to appreciate salmon in the wild. Additional policy guidance on relative to recovery planning applications of TRT products can be found on the following website: http://www.nwr.noaa.gov/Salmon-Recovery-Planning/ESA-Recovery-Plans/Other-Documents.cfm

In addition, the criteria we used to express viability facilitate the development of effective recovery strategies by focusing attention on specific, often spatially explicit, biological conditions or processes. For example, our criteria include quantitative metrics expressed in terms of the current distribution of spawners relative to spatially explicit maps of historical production potential within a population. We provide examples of the relative

risk associated with a range of general spawning area configurations. The descriptions of risk associated with alternative configurations provide recovery planners with an objective basis for targeting actions to address that component of viability. Our abundance and productivity criteria were designed to be used, in combination with current assessments, to inform recovery planning efforts as to the relative magnitude of changes in survival and habitat capacity needed to achieve viable status. They can also provide insight into whether productivity alone, or both productivity and capacity might need to be improved. Current status reviews developed by the ICTRT with input from regional technical teams will be compiled in a separate ICTRT document. We have included two current population status assessments with this report to illustrate application of the ICTRT viability criteria. Additional draft assessments are available at our website: http://www.nwfsc.noaa.gov/trt/trt_current_status_assessments.cfm.

Definitions

To understand the scope and focus of this report, it is useful to start with some definitions. The ESU and Population viability sections also include definitions of key terms and concepts. These definitions are intended to be consistent with current NMFS definitions and policy.

Biological viability criteria – Viability criteria are the primary focus of Part 1 of this report. Viability criteria describe biological or physical performance conditions that when met indicate a population or ESU is not likely to go extinct. Viability criteria have two components: a *metric*, which is the parameter measured, and the *criteria*, which are the values of the metric at which risk levels for a population or ESU are assigned. Viability criteria focus on the biological performance of the fish as the primary indicator of extinction risk. Viability criteria are intended to inform delisting criteria and therefore focus on metrics that can be used in current and future status evaluations. In 2005, NOAA published a policy in the Federal Register clarifying the role of hatchery production in risk assessments (70 FR 123: 37204). As currently being applied, the policy states that a non-listed ESU must be naturally self-sustaining and must be able to persist without input of hatchery-produced fish. The viability criteria described in this report are consistent with that standard.

Current status evaluation – A current ESU or population status evaluation is an assessment of the current extinction risk for populations and ESUs. Like viability criteria, current status evaluation relies on *metrics and thresholds.* However, viability criteria (as defined above) differ in an important way from current status evaluations. Current status evaluations are based on the information that is currently available on the ESU or population in question, whereas viability criteria describe those conditions under which populations might be considered to have a particular level of risk.

ESU scenario – The viability criteria described in this report allow for some flexibility in which populations will be targeted for a particular recovery level to achieve a viable ESU. An ESU scenario is an explicit description of which populations in an ESU are targeted for a given recovery level. Developing an ESU scenario requires both biological and policy considerations.

Relationship to Previous ICTRT Reports

Previous drafts of the ICTRT viability criteria were made available to provide guidance to regional recovery planning efforts that were ongoing concurrently with the development of these viability criteria. Early versions of the criteria were tested on some populations and refined based on lessons learned from the tests and input from regional recovery planners. We also have addressed technical peer review comments generated as a result of these early applications. The specific set of objectives and the particular measures associated with each component of our criteria have not changed. In some cases, the definition of certain risk levels in terms of a particular metric have been modified to facilitate more objective and consistent application of the criteria as well as to reflect new or better information as it became available. In addition, updates to the analyses used to estimate historical production capacity have resulted in changes in the assignment of some populations to a historical size category.

Considering Uncertainties

We recognize that uncertainty is an important consideration in setting risk criteria for natural populations. We considered categories of uncertainties in developing viability criteria for Interior Basin ESUs. First, some of our knowledge of the biological structure and functioning of specific ESUs is based on statistical sampling. Estimates of particular parameters are therefore subject to sampling variability. We provide results from sensitivity analyses to illustrate the potential effect of key uncertainties associated with several of our quantitative criteria. We encourage the use of multiple models or lines of evidence in assessing risk. Second, we provide options for directly incorporating a measure of uncertainty in evaluating current status. In addition, we identify topics for further scientific evaluation that could decrease uncertainties or lead to future improvements in particular criteria. Lastly, our criteria incorporate current understanding of environmental processes and their links to population dynamics. We encourage consideration of alternative future scenarios in developing strategies to achieve viability.

Organization

This report is organized into four sections. The initial section includes a general description of ESU hierarchical structure. The second section describes our ESU and Major Population Group (MPG) level criteria. The third section describes our population level criteria, including general examples and guidelines for using the criteria to determine the relative viability of a population. It also presents a method for generating an aggregate population risk rating and a discussion of approaches for addressing uncertainty in population viability metrics. The fourth section includes a summary of opportunities to improve or validate key assumptions through further monitoring and evaluation as well as a summary regarding application of the criteria described in this report. Appendices and attachments are included that provide more detailed technical analyses used in developing some of the population viability criteria, describe potential combinations of populations to achieve ESU viability and the role of repopulating extirpated areas in ESU viability, and provide some examples of application of population viability criteria.

Hierarchical Levels for Estimating ESU Viability

The ICTRT viability criteria reflect the hierarchical structure of Interior Columbia Basin ESUs (McElhany et al. 2000). In a previous ICTRT report, we described the structure of each Interior Columbia listed ESU in terms of discrete populations organized into Major Population Groups (Figure 1). Populations have been formally defined as a group of individuals that are demographically independent from other such groups over a 100-year time period (McElhany et al. 2000). We define Major Population Groups (MPGs) as sets of populations that share genetic, geographic (hydrographic), and habitat characteristics within the ESU (ICTRT 2003, 2005). They are analogous to "strata" as defined by the Lower Columbia-Upper Willamette TRT and "geographic regions" described by the Puget Sound TRT.

ESU Status

Major Population Group Status

Population Status

Abundance
Productivity
Spatial Structure
Diversity
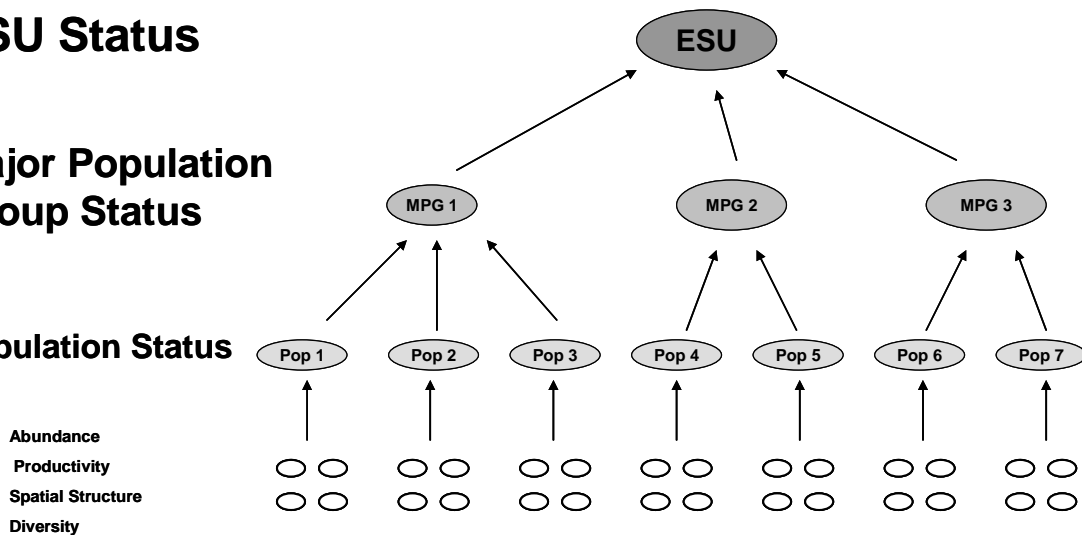
Figure 1. Diagram illustrating the hierarchy of ESU, MPG, and population level viability criteria.

At the population level, our viability criteria are expressed in terms of four attributes; abundance, productivity, spatial structure and diversity. The ICTRT designated major spawning areas (MaSAs) and minor spawning areas (MiSAs) as a framework for expressing within population spatial structure and diversity criteria (Appendix C).

Populations identified by the ICTRT range widely in terms of total tributary drainage area and complexity. Examples of populations occupying smaller drainages include Asotin Creek and Sulphur Creek (Snake River Steelhead and Spring/summer Chinook ESUs); Rock Creek and Fifteen Mile Creek (Middle Columbia ESU); and the Entiat River (Upper Columbia Steelhead and Spring Chinook ESUs). Populations using relatively large, complex tributaries include Upper John Day steelhead, Wenatchee and

Methow River Spring Chinook; and Lemhi River steelhead and spring/summer chinook. This natural variation in size and complexity suggests that even historically, populations likely varied in their relative robustness, or resilience to perturbations. Because of this variation, the TRT did not adopt a "one-size-fits-all" approach to population-level criteria. Considerations for relative population size and complexity characteristics are reflected in the population and Major Population Grouping viability criteria developed by the ICTRT. We provide population specific estimates of the amount and complexity of tributary spawning habitats in the Population Viability Criteria section of this report.

ESU/MPG Viability Criteria

McElhany et al. 2000 identifies three factors to consider in assessing the viability of an ESU in terms of its component populations: 1) catastrophic events, 2) long-term demographic processes and 3) long-term evolutionary potential. Catastrophic events are localized, relatively sudden impacts that can severely reduce or eliminate a population. The potential for these types of events impacting a particular population are not usually captured in short-term (e.g., 10 to 100 year) assessments of annual environmental variations. Long-term demographic processes relate to the potential for recolonization of locally extirpated populations within an ESU from other populations. Evolutionary potential of an ESU relates to the role diversity plays in ESU viability. Both of these processes operate on time scales extending out to hundreds of years.

ICTRT ESU Criteria

The major objectives of our ESU/MPG level viability criteria are to ensure preservation of basic historical metapopulation processes including: 1) genetic exchange across populations within an ESU over a long time frame; 2) the opportunity for neighboring populations to serve as source areas in the event of local population extirpations; 3) populations distributed within an ESU so that they are not all susceptible to a specific localized catastrophic event. To meet these objectives a viable ESU will likely have some populations meeting viability standards close to each other AND some populations meeting viability standards relatively distant from each other (McElhany et al. 2000, Isaak et al. 2003).

A variety of recovery scenarios may lead to a viable ESU. Different scenarios of ESU recovery may reflect alternative combinations of viable populations and specific policy choices regarding acceptable levels of risk. The particular recovery objectives for Interior Columbia ESUs will be generated by policy and technical interactions in conjunction with regional planning efforts. We provide the following criteria to describe the biological characteristics of a viable ESU to inform the development of specific recovery objectives for Interior Columbia ESUs.

Our ESU-level viability criterion is:

All extant MPGs and any extirpated MPGs critical for proper functioning of the ESU should be at low risk.

We express our ESU viability criterion in the context of Major Population Groups (MPGs)—geographically and genetically cohesive groups of populations within an ESU that are thus critical components of ESU-level spatial structure and diversity. Historically, these groupings of populations within an ESU likely functioned as metapopulations—formally defined as sets of discrete, largely independent populations whose dynamics are driven by local extinction and with limited interbreeding and

recolonization among populations (after Levins,1969). We do not have sufficient information on movement or exchange rates among Interior Columbia Basin populations to directly model MPGs or ESUs as metapopulations. We have defined MPG-level viability criteria to ensure robust functioning at the metapopulation level and mitigate the risk of catastrophic loss of one or more populations. MPG viability depends on the number, spatial arrangement, and diversity associated with its component populations. Criteria for evaluating the relative viability of a population are provided in the following section of this report.

We have developed the following MPG-level criteria considering relatively simple and generalized assumptions about movement or exchange rates among individual populations (details for population viability are provided in the next section).

An MPG meeting the following five criteria would be at low risk:

1. **At least one-half of the populations historically within the MPG (with a minimum of two populations) should meet viability standards.**

2. **At least one population should be classified as "Highly Viable."**

3. **Viable populations within an MPG should include some populations classified (based on historical intrinsic potential) as "Very Large", "Large" or "Intermediate" generally reflecting the proportions historically present within the MPG. In particular, Very Large and Large populations should be at or above their composite historical fraction within each MPG.**

4. **All major life history strategies (e.g. spring and summer run-timing) that were present historically within the MPG should be represented in populations meeting viability requirements.**

5. **Populations not meeting viability standards should be maintained with a) sufficient productivity so the overall MPG productivity does not fall below replacement (i.e. these areas should not serve as significant population sinks) and b) sufficient spatial structure and diversity demonstrated by achieving Maintained standards.**

The ICTRT ESU/MPG criteria follow the basic guidelines provided in McElhany et al. 2000. The specific rationale for the individual components of our MPG/ESU level criteria are described below.

Minimum Number of Viable Populations

Modeling efforts incorporating spatial structure, local and correlated catastrophes and dispersal suggest that extinction risk of a metapopulation as a whole decreases rapidly as additional viable populations are added to the group (Ruckelshaus et al. 2003, 2004, Tear et al. 2003). Kendall et al. (2001), in conducting a PVA of Gila Trout, found that

extinction risk was highly sensitive to the number of populations included in the model. Rieman and Dunham (2000) and Fagan (2002) discuss the importance of metapopulation structure to overall risk for fish populations occupying dendritic habitats as well as the associated difficulties in accurately modeling particular situations. Based on these analyses, we generally conclude that an MPG containing only one viable population would be at substantially greater risk of extirpation than one with two or more populations, and that additional populations present within an MPG would further decrease the risks to the functioning of the MPG.

We recommend that a minimum of one-half of the populations historically present (but no less than 2) within an MPG be viable based on two major consideration. First, having multiple viable populations can provide a spatial distribution that provides for normative dispersal and gene flow among populations while still supporting within-MPG diversity. Second, because populations that are close to each other are more likely to have some demographic linkage (Bentzen et al. 2001), having multiple viable populations reduces extinction risk due to local catastrophic events. Reducing extinction risk related to catastrophic events typically requires a reasonable proportion of the populations within the MPG. Connectivity among populations in the MPG is expected to increase as the number of viable populations increases and distances between proximate populations decreases. Kendall et al. (2001) linked increased connectivity to increased recolonization of populations subject to catastrophic losses and improved viability of Gila trout. We expect this same principle applies to the metapopulation-like structure of an MPG and increased viability of the MPG is achieved by having multiple viable populations. An objective for the combinations of Viable and Maintained populations required to meet our MPG criteria is achieving a composite MPG productivity at or above replacement, thus ensuring long-term persistence of the ESU (Holmes and Semmens, 2004, Gunderson et al. 2001).

Achieving viability goals for the minimum number of populations will likely require attempting to meet those targets in more than just those populations because the efficacy of recovery efforts is uncertain. For example, if there is an 80% chance that recovery will be successful in each of a set of three populations identified, there is an overall 51% probability of recovering three populations if recovery efforts are limited to those three populations (McElhany et al. 2003). To have more than a 95% probability of recovering three populations in this case would require attempting recovery of six populations. Consequently, more populations than the minimum should be targeted for viability. This strategy would also address the uncertainty inherent in the assumption that 2 or half of the populations in an MPG are adequate for viability.

Include Highly Viable populations

The ICTRT recommends that at least one population within each MPG should be Highly Viable, following the recommendation in McElhany et al. (2000) The presence of highly viable populations distributed across the ESU provides source populations that can recolonize populations that have experienced catastrophic losses (McElhany et al. 2000; Gunderson et al. 2001). Also, achieving a higher level of viability for a subset of populations scattered across the ESU provides some protection against future

environmental conditions substantially deviating from historical patterns.

Population Sizes Represented

We include recommendations for the size distribution of populations within an MPG for a similar reason—large populations are more likely to have served historically as "source" areas for the group of populations (McElhany et al. 2000) In addition, larger populations almost always consist of 2 or more relatively discrete production areas, each of which was capable of sustaining 500 or more spawners. From the perspective of localized catastrophic risks, these populations are at lower risk of total loss for a brood cycle or longer than populations confined to a single sub watershed or mainstem reach. An MPG consisting of small populations at low risk and large populations at relatively higher risk is likely to be at higher risk overall than one that includes large populations in a low-risk condition.

Major Life History Patterns Represented

Major life history variations (e.g., spring vs. summer adult run timing and the associated differences in spawning timing/areas) represent an important component of the diversity within an ESU. These major life history patterns represent adaptations to the range of environmental conditions experienced by populations across the historical range of an ESU. Requiring the security of low-risk levels for at least one population representing each historical life history variation within an MPG provides a basis for the ESU to adapt to future conditions.

Maintained Populations

Our criteria focus efforts at recovering a minimum number of populations within each MPG to viable levels. In many cases there will be one or more additional extant populations within an MPG. The ICTRT established the maintained criterion for application to these populations. The primary intent is to avoid situations where one or more of these populations serve as an overall 'sink' for production across an MPG. In addition, meeting the maintained criterion for these populations contributes to connectivity within and among MPGs and promotes the preservation of genetic and life history diversity. The Population Viability Criteria section below includes a discussion of objectives and criteria for maintained populations. This recommendation is analogous to the element of the Lower Columbia/Willamette TRT viability criteria that stipulates that populations not meeting viability criteria be maintained at a levels providing ecological and evolutionary function to the ESU as a whole (McElhany et al. 2003).

Combined Effects of Meeting MPG Criteria

Having all MPGs within an ESU at low risk addresses the three ESU level considerations identified by McElhany et al. 2000. Protection against long-term impacts of localized catastrophic loss is gained by the presence of multiple, relatively nearby viable and maintained populations to serve as a source of re-colonization. MPGs were defined, in a large part, based on genetic and ecological differentiation. For example, Figure 2

illustrates the range in elevation associated with historical spawning reaches for Snake River Spring-Summer Chinook ESU populations. Annual temperature and precipitation patterns are substantially influenced by elevation. The ICTRT criteria requiring viable populations in each of the five extant MPGs of this ESU would result in sustainable production across a substantial range in environmental conditions. The presence of viable populations across MPGs would preserve a high level of ESU diversity, thereby promoting long-term evolutionary potential for adaptation to changing conditions. This criterion is also consistent with recommendations for other ESUs in the Pacific Northwest (e.g., McElhany et al. 2006, PSTRT, 2002).
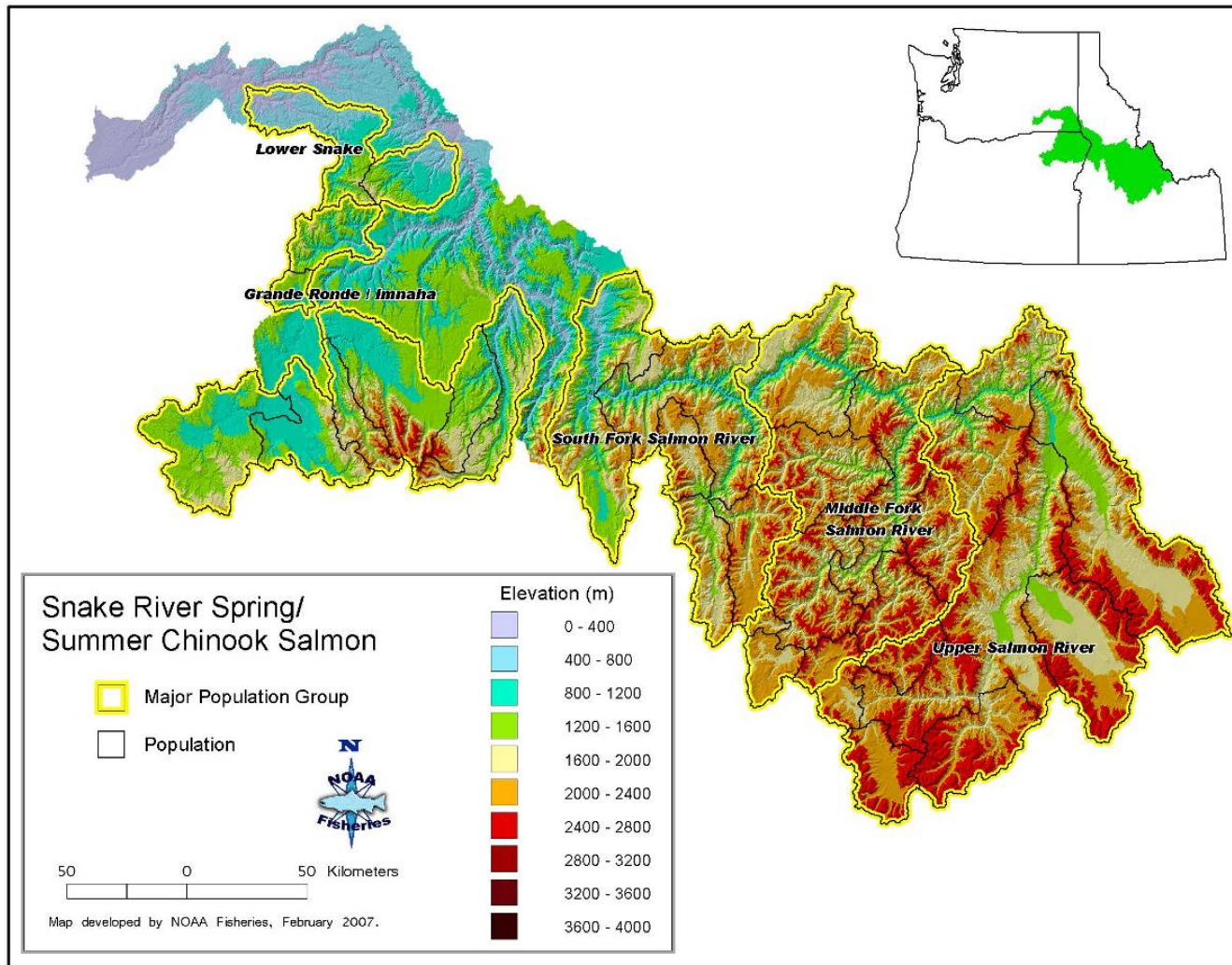
Figure 2.a. Snake River Spring/Summer Chinook ESU distribution of populations and Major Population Groups (MPGs) relative to elevation.

Snake River Spring/Summer Chinook ESU
Spawning Elevation Ranges (Intrinsic)
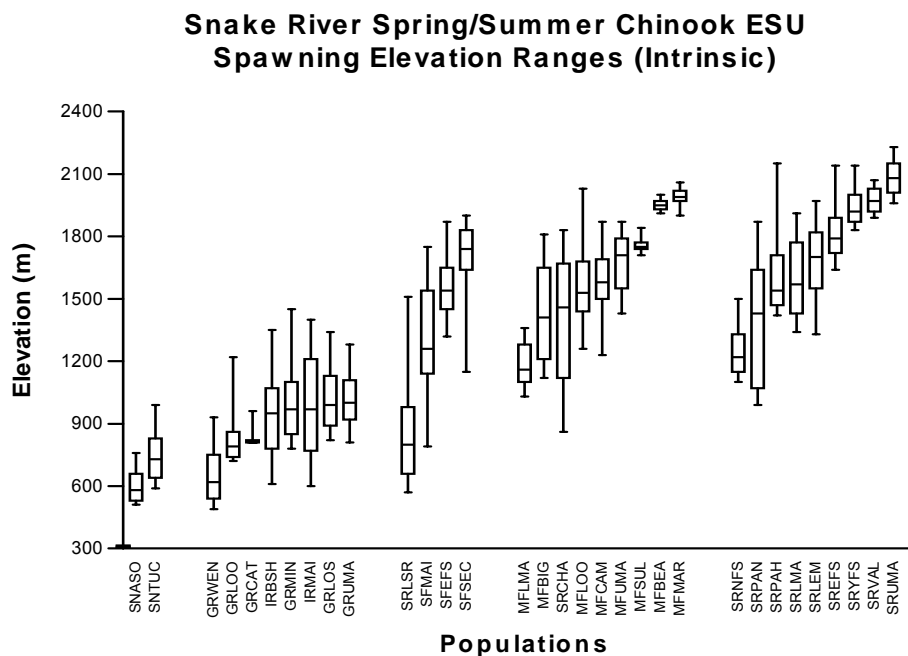
Figure 2.b. ESU Snake River Spring/Summer Chinook population median elevations. Boxes represent the range of elevation in the middle 50% of the population, while bars represent the middle 90%.

ESUs with a single MPG

ESUs that contain only one MPG are inherently at greater extinction risk due more limited spatial structure and diversity and potentially abundance and productivity. In addition, they typically have fewer component populations, which also increases risk level (Boyce 1992, Tear et al. 2003). We provide more stringent criteria for ESUs with a single MPG than ESUs with multiple MPGs to mitigate this inherently higher risk.

ESUs that contained only one MPG historically or that include only one MPG critical for proper function should meet the following criteria:

- A single MPG should meet all the requirements to be at low risk (see above). In addition:

  1. Two-thirds or more of the historical populations within the MPG should meet viability standards; AND

  2. At least two populations should meet the criteria to be "Highly Viable."

Extirpated MPGs

The ICTRT has conducted an evaluation to determine whether extirpated MPGs are critical for proper functioning of the ESU (see Attachment 1). The evaluation was based on the following general considerations:

- Likely demographic (abundance and productivity) contribution of the MPG and its component populations to the ESU.

- Spatial role of the MPG in the ESU (e.g. does the extirpated MPG create a gap in the distribution of the ESU?)

- Likely contribution to overall ESU diversity (e.g. does the extirpated MPG occupy habitats that are substantially different from other habitats currently occupied in the ESU?)

Alternative Recovery Scenarios

Three of the listed Interior Columbia ESUs include four or more MPGs (major population groups) each of which contains multiple extant populations (Tables 2a-c). In those circumstances, there can be several different viable population scenarios at the MPG level that would meet the ICTRT viability criteria. We have summarized potential viability scenarios for each ESU in a ICTRT memo (Attachment 1). In addition, the role of large extirpated areas on the overall risk for an ESU varies with the characteristics of the currently accessible areas. We treat the likely changes in risk that would result from the establishment of self-sustaining populations in these extirpated areas in a second memo (Attachment 2).

Population Level Viability Criteria

Here, we describe the criteria for use in assessing viability at the individual population level. We have grouped specific population level criteria into two basic subsets; measures addressing abundance and productivity and a set reflecting spatial structure/diversity elements. We also present a framework for compiling an aggregate risk score for a population based on the results of applying the individual criteria.

Historical Populations: Size and Complexity

Populations of listed stream type chinook salmon and steelhead within the Interior Columbia River vary considerably in terms of the total area available to support spawning and rearing. The ICTRT developed a method for adapting viability curves to reflect estimates of the historical amount of potentially accessible spawning and rearing habitat available to a specific population. A more detailed description of the approach is provided in Appendix B. The measure of historical habitat we used is primarily driven by spawning habitat considerations. We emphasize spawning population size in these viability assessments because of the direct link to population genetic characteristics, demographics, etc. The same habitat characteristics we used in the assessment generally reflect relative juvenile production potential, but we recognize that an analysis focused on estimating the relative amount of juvenile habitat would recognize additional combinations of habitat characteristics. Analyses aimed at evaluating limiting factors or the potential effects of proposed habitat actions should consider juvenile rearing habitat. We initially focused on an application for stream type chinook and steelhead populations because of the availability of representative data sets and the relative number of listed ESU populations. We adapted the approach to accommodate the biological characteristics and available data for Snake River Fall Chinook and Snake River Sockeye populations, respectively.

Estimating Historical Capacity

In summary, a measure of the historic spawning/rearing area for each population was generated using a simple model of historical intrinsic potential. That model is driven by estimates of stream width, gradient, valley width, and confinement derived from a GIS-based analysis of the tributary habitat associated with each population. Additional screens were added for steelhead intrinsic potential that included sediment, soil erodibility and flow velocity. Each accessible 200 meter reach within the tributary habitat associated with a specific population was assigned an intrinsic productivity rating based on the particular combination of physical habitat parameters listed above. A weighted estimate of the total amount of rated habitat historically available to each population was generated. The habitat ratings for each potential spawning reach were assigned a relative weighting and summed by population

We established a set of four population size categories (Basic, Intermediate, Large and Very Large) for Interior basin stream type chinook and steelhead populations. For each species, populations were ordered and grouped according to the estimated amount of historical spawning/rearing habitat (Appendix B). Two considerations were used to determine breakpoints

between category assignments: median size of populations within a putative grouping and the occurrence of relatively large incremental differences between adjacent populations in the species sequences. The smallest populations were grouped into the Basic size category. Populations assigned to the Basic size categories tended to be simple in complexity, often with a relatively linear arrangement of spawning/rearing reaches. Median population size roughly doubled between size categories. Populations with significantly higher amounts of potential spawning habitat usually exhibited a higher degree of spatial diversity—e.g., multiple tributary branches. Contemporary redd survey results indicated that the distribution of spawners across sub areas within a population was likely to be patchy. Relatively high spawning concentrations in particular subareas could be achieved in the larger, more complex population at lower overall spawning densities. Size category assignments for the specific populations within each of the listed Interior Columbia ESUs are provided in Tables 2a-e. Relative population size estimates for Snake River Fall chinook and sockeye populations are described in Appendix B.

Population Spatial Complexity

We used two methods to characterize the relative within-population complexity of tributary spawning habitats—assigning each population to one of four general structural complexity categories (Table 1), and estimating the number of relatively large, contiguous production areas within each population (Appendix C). We hypothesize that the increased protection against catastrophic loss provided by multiple large spawning areas within a single population would be analogous to the risk reduction associated with having multiple independent populations within an ESU. We defined an empirical, data-based measure of potential spawning habitat as a baseline for our criteria. We defined a branch as a river reach containing sufficient habitat to support 50 spawners. Major spawning areas (MaSAs) were defined as a system of one or more branches that contain sufficient habitat to support 500 spawners. For spring/summer chinook, this value was 100,000m^2, and for steelhead it equaled 250,000m^2. We generated aggregation values by using hydrology tools within GIS (see Appendix C). We defined contiguous production areas capable of supporting between 50 and 500 spawners as minor spawning areas (MiSAs).

Table 1. Population spatial complexity designations

Category	Description
A.	Linear structure, with no more than 2 branches in one major spawning area. Typically small (basic) drainages.
B.	Dendritic tributary structure including 2 or more major spawning areas. Typically intermediate or large drainages.
C.	Trellis-structured drainage including mainstem spawning and multiple branches.
D.	Populations with one or more major spawning areas with well-separated minor spawning areas downstream.

Stream Type Chinook and Steelhead Populations

Each population was assigned to a size category based on the total amount of weighted spawning habitat and given a complexity rating based on the estimated relative distribution of historical spawning habitat (Tables 2a-e).

Table 2.a. Intrinsic size and complexity ratings for **extant Snake River Spring Chinook ESU** populations organized by Major Population Groupings. Complexity categories: A = linear; B=dendritic; C= trellis pattern; D= core drainage plus adjacent but separate small tributaries. Underlined entries represent a change from the previous designation. Size categories in parentheses represent core tributary production areas.

Major Population Group	Population	Weighted Area Category	Complexity	
			Category	#MaSA (#MiSA)
Lower Snake	Tucannon R	Intermediate	A	1 (0)
	Asotin R. (ext)	Basic	A	0 (1)
Grande Ronde/Imnaha R	Lostine/Wallowa R.	Large	B	3 (1)
	Upper Grande Ronde R.	Large	B	3 (2)
	Catherine Creek	Large	B	2 (2)
	Imnaha R. Mainstem	Intermediate	A	1 (1)
	Minam R.	Intermediate	A	2 (0)
	Wenaha R.	Intermediate	A	1 (0)
	Big Sheep Cr. (ext)	Basic	A	0 (1)
	Lookingglass Cr. (ext)	Basic	A	0 (1)
South Fork Salmon	South Fk Mainstem	Large	C	2 (2)
	Secesh R.	Intermediate	A	1 (1)
	East Fk/Johnson Cr.	Large	B	2 (0)
	Little Salmon R.	Inter. (Basic)	D	0 (3)
Middle Fork Salmon	Big Creek	Large	B	3 (0)
	Bear Valley	Intermediate	C	3 (0)
	Upper Mainstem MF	Intermediate	C	1 (2)
	Chamberlain Cr.	Inter. (Basic)	D	1 (3)
	Camas Creek	Basic	B	1 (1)
	Loon Creek	Basic	C	1 (0)
	Marsh Creek	Basic	C	1 (0)
	Lower Mainstem MF	Basic	A	0 (1)
	Sulphur Creek	Basic	A	1 (0)
Upper Salmon	Lemhi	Very Large	B	3 (2)
	Lower Mainstem	Very Large	C	3 (5)
	Pahsimeroi	Large	B	5 (0)
	Upper Salmon East Fk	Large	C	1 (0)
	Upper Salmon Mainstem	Large	C	3 (0)
	Valley Cr.	Basic	A	1 (0)
	Yankee Fork	Basic	C	1 (0)
	North Fork Salmon R.	Basic	D	1 (0)
	Panther Cr. (ext)	Intermediate	C	1 (2)

Table 2.b. Intrinsic size and complexity ratings for historical **Snake River Steelhead ESU** populations organized by Major Population Groupings. Complexity categories: A = linear; B=dendritic; C= trellis pattern; D= core drainage plus adjacent but separate small tributaries. Size categories in parentheses represent core tributary production areas.

Major Population Group	Population	Weighted Area Category	Complexity	
			Category	#MaSA (#MiSA)
Lower Snake	Tucannon R	Intermediate	A	1 (2)
	Asotin R.	Basic	D	2 (5)
Grande Ronde	Upper Grande Ronde R.	Large	B	6 (7)
	Wallowa River	Intermediate	B	4 (2)
	Lower Grande Ronde R.	Intermediate	B	2 (5)
	Joseph Creek	Basic	B	3 (3)
Imnaha R.	Imnaha River	Intermediate	B	4 (3)
Clearwater R.	Lower Mainstem	Large	B	6 (5)
	Selway River	Intermediate	B	7 (6)
	South Fork	Intermediate	B	3 (4)
	Lochsa River	Intermediate	B	3 (5)
	Lolo Creek	Basic	C	1 (0)
	North Fork (ext)	Large	B	---
Salmon River	Lemhi	Intermediate	B	3 (2)
	Upper Salmon East Fork	Inter. (Basic)	B	2 (1)
	Upper Salmon Mainstem	Intermediate	B	5 (2)
	Upper Middle Fork	Intermediate	B	6 (3)
	Lower Middle Fork	Intermediate	B	5 (2)
	Chamberlain Cr.	Basic	D	1 (5)
	Pahsimeroi River	Intermediate	C	3 (2)
	Panther Cr	Basic	D	1 (3)
	Little Salmon River	Inter. (Basic)	D	1 (4)
	South Fork	Intermediate	B	3 (4)
	Secesh R.	Basic	C	1 (1)
	North Fork	Basic	D	1 (1)
Hells Canyon Tributaries	Wild Horse/Powder R.	Note: Core spawning areas for this population are blocked to anadromous migration.		

Table 2.c. Intrinsic size and complexity ratings for historical populations within the **MIDCOLUMBIA RIVER STEELHEAD ESU**. Organized by Major Population Groupings. Complexity categories: A = linear; B=dendritic; C= trellis pattern; D= core drainage plus adjacent but separate small tributaries. Size categories in parentheses represent core tributary production areas.

Major Population Group	Population	Weighted Area Category	Complexity	
			Category	# MaSA (# MiSA)
Eastern Cascades	Deschutes (westside)	Large (Inter.)	B	5 (9)
	Deschutes (eastside)	Intermediate	B	6 (4)
	Klickitat River	Intermediate	B	6 (4)
	Fifteenmile Creek	Basic	C	3 (5)
	Rock Creek	Basic	A	1 (0)
	Crooked River (ext.)	Very Large	B	---
	White Salmon (ext)	Basic	C	---
Yakima River	Upper Yakima River	Large	B	14 (2)
	Naches River	Large	B	8 (2)
	Toppenish River	Basic	B	2 (1)
	Satus Creek	Intermediate	B	3 (4)
John Day River	John Day Lower Mainstem	Very Large	B	13 (22)
	John Day North Fork	Large	B	10 (5)
	John Day Upper Mainstem	Intermediate	B	3 (4)
	John Day Middle Fork	Intermediate	B	4 (2)
	John Day South Fork	Basic	B	3 (0)
Umatilla/Walla Walla	Umatilla River	Large	B	13 (3)
	Walla-Walla Mainstem	Intermediate	B	5 (6)
	Touchet River	Intermediate	A	1 (0)
	Willow Cr. (ext)	Intermediate	B	---

Table 2.d. Intrinsic size and complexity ratings for historical populations within the **UPPER COLUMBIA RIVER SPRING CHINOOK ESU**. Organized by Major Population Groupings. Complexity categories: A = linear; B= dendritic; C= trellis pattern; D= core drainage plus adjacent but separate small tributaries.

Major Population Group	Population	Weighted Area Category	Complexity	
			Category	# MaSA (# MiSA)
Eastern Cascades	Wenatchee	Very Large	B	5 (4)
	Methow	Very Large	B	4 (1)
	Entiat	Basic	A	1 (0)
	Okanogan River (ext) (US portion only) [1]	Intermediate	D	1 (3)

[1] Spring Chinook historically occupied tributary habitat in both the U.S. and Canada. Current ICTRT analyses are focused on the US portion, although additional MSAs or populations may exist in the Canadian portion.

Table 2.e: Intrinsic size and complexity ratings for historical populations within the **UPPER COLUMBIA STEELHEAD ESU**. Organized by Major Population Groupings. Complexity categories: A = linear; B= dendritic; C= trellis pattern; D= core drainage plus adjacent but separate small tributaries.

Major Population Group	Population	Weighted Area Category	Complexity	
			Category	# MaSA (# MiSA)
Eastern Cascades	Wenatchee River	Intermediate	B	7 (8)
	Methow River	Intermediate	B	5 (5)
	Entiat River	Basic	A	1 (1)
	Okanogan River (US portion only) [1]	Intermediate	B	2 (6)
	Crab Creek (ext)	Intermediate	D	1 (2)

[1] Steelhead historically and currently occupy tributary habitat in both the U.S. and Canada. Current ICTRT analyses are focused on the US portion, although additional MSAs or populations may exist in the Canadian portion.

Snake River Fall Chinook and Sockeye Populations

The ICTRT adapted the approach for identifying major and minor spawning areas as follows to reflect biological characteristics of Snake River fall chinook and sockeye. Appendix B includes specific details of our analysis of the relative amount of historical spawning/rearing habitat within populations of these two ESUs.

The extant Snake River fall chinook population includes five MaSAs: the two mainstem reaches described above along with the lower reaches of the Clearwater, Grand Ronde and Tucannon Rivers. The lower reaches of the Imnaha and Salmon Rivers may have supported relatively low levels of fall chinook spawning and are considered part of the upper mainstem MaSA.

A number of lakes ranging widely in size within the Columbia River basin historically supported sockeye production (see appendix B). The relative productivity of sockeye populations is generally correlated with lake surface area (Burgner, 2001). With the exception of Redfish Lake, the Stanley Basin lakes have been at the lower end of the size range of the Columbia River basin sockeye lakes. Redfish Lake falls into an intermediate size category based on surface area.

We have little information on the within population structure of the Redfish Lake sockeye. Based on recent observations, sockeye spawn along the lake shore in October and November (Good et al., 2005). Given the extremely low levels of Snake River sockeye returns, initial recovery efforts are largely focused on improving survival rates of out-migrant smolts. More detailed information on the spatial structure of the Stanley Basin lake populations may be generated as recovery efforts progress.

Abundance and Productivity

Risk of extinction at the population level can be directly related to the combination of abundance and productivity of a particular population. The VSP guidelines for abundance and productivity developed by McElhany et al. 2000 provide the rationale for considering these two parameters in combination. The VSP guidelines for abundance recommend that a viable population should:

- Be large enough to have a high probability of surviving environmental variation observed in the past and expected in the future;

- Be resilient to environmental and anthropogenic disturbances; maintain genetic diversity; and support/provide ecosystem functions;

- Demonstrate sufficient productivity to support a net replacement rate of 1:1 or higher at abundance levels established as long-term targets;

- Demonstrate productivity rates at relatively low numbers of spawners that, on the average, are sufficiently greater than 1.0 to allow the population to rapidly return to abundance target levels after perturbations.

A viable population should exhibit an average abundance high enough to result in compensatory (density dependent) processes providing some resilience to annual perturbations. This resilience results from increases in relative productivity due to reduced density dependent effects when abundance fluctuates to lower levels (McElhany et al. 2000).

Marine survival is a major factor contributing to annual variability in return rates of Interior Columbia anadromous salmonid populations (e.g., Deriso et al. 2001, Zabel et al. 2006). Indices of marine survival for Interior ESUs demonstrate relatively high level of year to year correlation in annual returns. Achieving a desired risk level for populations subject to relatively high levels of autocorrelation in annual return rates may require a higher combination of abundance and productivity to provide for rebuilding from consecutive bad years (e.g., Morris & Doak, 2002).

ICTRT Abundance & Productivity Objective:

We developed the following objective for our population level abundance and productivity criteria considering the specific VSP guidelines summarized above:

Intrinsic productivity and natural origin abundance should be high enough that 1) declines to critically low levels would be unlikely assuming recent historical patterns of environmental variability; 2) compensatory processes provide resilience to the effects of short term perturbations; and 3) subpopulation structure is maintained (e.g., multiple spawning tributaries, spawning patches, life history patterns).

We developed a quantitative metric for evaluating the abundance and productivity of a population. Specifically, we defined "viability curves" (e.g., LCWTRT, 2003) for each ESU. A viability curve describes those combinations of abundance and productivity that yield a particular

risk or extinction level at a given level of variation. The two parameters are linked relative to extinction risks associated with short-term environmental variability. Given a particular productivity level, populations at higher levels of abundance are more resilient in the face of year to year variability in overall survival rates than smaller populations. Populations with relatively high intrinsic productivity (expected ratio of spawners to their parent spawners at low levels of abundance) are also more robust at a given level of abundance relative to populations with lower intrinsic productivity.

Viability curves are generated via a population viability analysis (PVA) incorporating metrics representative of the target population. While PVAs can vary widely in levels of detail and quantification, all PVA applications include some means of assessing the risk of reaching a specified threshold or evaluating rates of change in abundance over time.

There is a general consensus among reviews of PVA applications on the importance of expressing the results of PVA analyses in an appropriate context, including explicit recognition of the potential influence of key uncertainties (e.g., Brook et al., 2002). Two broad categories of uncertainty can have a significant influence on the results of a PVA analysis: 1) uncertainty regarding the form of the relationship between parent abundance and subsequent production; and 2) uncertainties generated by limited abilities to include all potential environmental factors. We have explicitly recognized these factors in developing and presenting results from PVA models for Interior Columbia salmonid populations. We conducted sensitivity analyses relating model outputs to a range of values for key input variables. We contrast projected risk metrics under alternative mathematical forms of the underlying stock production relationship. We also simulated the potential influence of measurement errors on model input parameters and on projected risk levels. In addition, uncertainty regarding future environmental and human induced conditions that affect key population rates and processes should be taken into account in considering the implications of a PVA analysis. We incorporate alternative future environmental scenarios into our current status assessments.

Viability Curves: Key Components and Definitions

Generating a viability curve requires an estimated extinction or quasi-extinction threshold, an estimate of the variability in productivity, and a target risk level (e.g. 5% in 100 years). We describe the derivation of viability curves for application to Interior Columbia populations in Appendix A. A brief summary of our approach, including the rationale for particular input assumptions, is provided below.

A specific viability curve is defined as the combinations of abundance and productivity corresponding to a particular extinction risk (Figure 3). In general terms, high abundance combined with moderate productivity could provide the same extinction risk as that of a lower abundance but higher productivity. We incorporate a minimum abundance threshold into our viability curves to address genetic and spatial structure components of our general abundance and productivity objectives. Combinations of abundance and productivity falling above the curve would result in lower extinction risk, whereas points below the curve represent higher risk. We developed viability curves corresponding to a range of extinction risks (1%, 5%, and 25% level in 100 years). We use a quasi-extinction threshold to represent extinction in generating

viability curves. We define our viability curves in terms of a simple linear Hockey-stick density-dependent relationship. A particular viability curve is a function of a set of representative assumptions regarding population dynamics and environmental variation. Sets of viability curves were generated using ESU-specific estimates of age structure and variability in brood year productivity (including autocorrelation in annual return rates). Theoretical studies have indicated that high autocorrelation in population abundance trend data can influence projected risks in a PVA analyses (e.g., Morris & Doaks, 2002, Wichmann et al. 2005). Our evaluations of Interior Columbia stream type chinook and steelhead data series indicated strong short term autocorrelation in abundance and productivity (see appendix A).
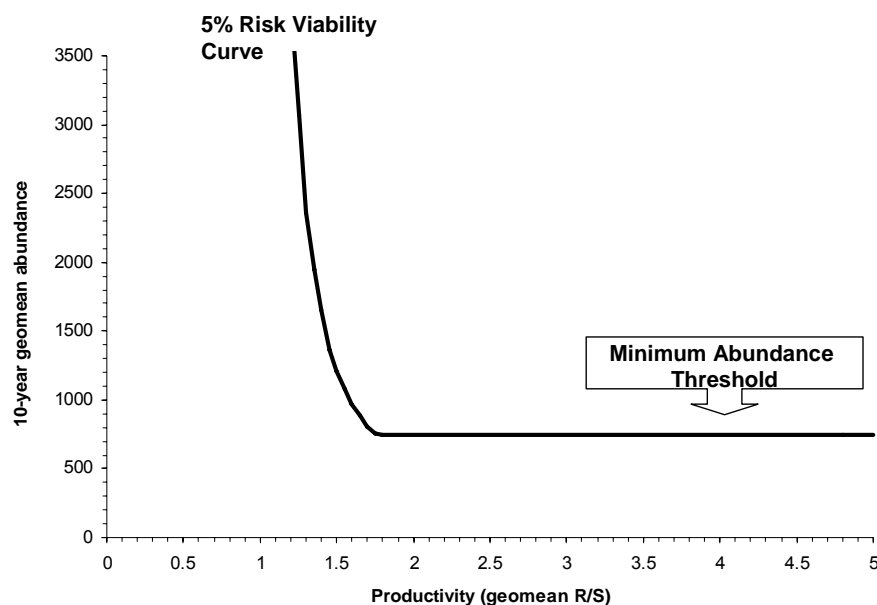
Figure 3. Example of a viability curve incorporating a minimum abundance threshold. The curve defines combinations of abundance and productivity values corresponding to a 5% risk of extinction over a 100 year period while maintaining average abundance at or above a minimum level set to avoid maladaptive genetic effects and to address spatial complexity objectives.

Risk Levels vs. Viable Status

The ICTRT population level viability criteria are expressed relative to an acceptable risk level of a 5% probability of extinction in a 100-year period. The level of risk is consistent with VSP guidelines and the conservation literature (McElhany et al. 2000; NRC, 1995). In addition, NOAA Fisheries has given previous policy guidance that a 5% risk of extinction over a 100-year period is an appropriate benchmark for population level risk assessment, at least for initial exploration. We chose to express the risk relative to a 100 year time from for several reasons; 1) it incorporates sensitivities to multiyear patterns/variations in environmental influences, 2) it is an appropriate time frame for considering recovery strategies that include habitat restoration actions that may take considerable time to result in survival improvements (e.g., restoring riparian habitat or stream structure to enhance parr to smolt survivals) and 3) a 100 year time

frame subsumes short time frame risks. Under historical conditions, most populations within the region would have been rated as very low risk relative to the 5% viability curve. At the population level, recovery strategies should be targeted to achieving combinations of abundance and productivity above the 5% viability curve threshold. We recognize that alternative risk levels and time frames may be useful in assessing population status when considering short term effects of actions, etc.

Form of Spawner-Recruit relationship

We have provided ESU specific viability curves based on relatively simple and direct measures of abundance and productivity. In most cases, data used to evaluate current status will be based on a relatively limited number of years. Uncertainty levels and bias in parameter estimates can be very large. Therefore it is especially important that assessments employing fitted stock recruit curve parameters as an index of current productivity should directly incorporate considerations for sampling induced errors and bias in their assessments. We describe methods for minimizing the potential impact of sampling induced bias and error in the current status application section of this report.

We used a hockey-stick form of density-dependence to underlie our viability curves. However, we recognize that it is possible to express the productivity term in a viability curve in terms of a stock-recruitment function, e.g., Beverton-Holt or Ricker curves. There is substantial potential for error or systematic bias in estimates generated using curve fitting techniques, especially when a data series is relatively short and highly variable (e.g., Hilborn & Walters, 1992). Approaches to risk assessment based on empirical curve fitting should explicitly incorporate methods to reduce the impact of error and bias. In some cases, error or bias can be reduced by the choice of an appropriate statistical framework (e.g., Myers & Mertz, 1998, Mackinson et al. 1999, Michielsens & McAllister, 2004) or by incorporating independent variables that account for components of the overall variability in annual return rates (e.g., Morris & Doak, 2002).

Extinction Definition (Quasi-extinction thresholds)

We implemented a QET of 50 spawners per year over a consecutive four-year period in generating viability curves for application to Interior Columbia basin ESU populations. Four consecutive years represents a full brood cycle of adult (mature male and female spawners). A quasi-extinction threshold is defined as "..the minimum number of individuals (often females) below which the population is likely to be critically and immediately imperiled." (Morris & Doaks, 2002; Ginsburg et al. 1982). We selected 50 as a QET based on four considerations; consistency with theoretical analyses of increasing demographic risks at low abundance, uncertainty regarding low abundance productivity of Interior Columbia ESU populations due to the paucity of escapements less than 50 spawners in the historical record, sensitivity analyses indicating that the probability of multiple very low escapements increases substantially as the QET approaches 1 spawner per year, and consistency with applications by the Puget Sound and the Lower Columbia/Willamette TRTs (McElhany et al. 2003, 2006).

There is a substantial theoretical basis for employing a QET in population viability analyses (e.g., Morris and Doak, 2002). However, there is also a clear recognition of the problems

inherent in identifying a single best fit value for any given population. It is generally recognized that relative productivity would be expected to drop off at extremely low abundance. Three factors contributing to highly elevated extinction risk at very low abundance are demographic stochasticity, Allee effects, and increased risk of permanently losing genetic variability. (e.g. McElhany et al. 2000). Demographic stochasticity reflects the impact of random events and processes at relatively small population sizes. Contributing factors would include mate selection, sex ratios and individual fecundity. Allee effects are reductions in relative productivity at low abundance due to factors such as ineffective mate pairing (Morris and Doak, 2002).

The Recovery Science Review Panel (RSRP) provided general guidance to the TRTs on the use of PVA models based on a literature review. The review supported the concept of a QET – recommending that "…PVA analyses be conducted evaluating the risk of population decline to a threshold N*, above which demographic stochasticity, Allee effects, and even genetic effects of inbreeding depression, can be largely ignored." The RSRP noted that demographic stochasticity generally can be ignored at mature population sizes of 100 and that more precise estimates for application in particular situations could be generated based on a ratio of estimated demographic to environmental stochasticities.

The productivity of Interior Columbia basin salmon and steelhead populations at very low annual spawning abundance is highly uncertain. We evaluated historical spawning abundance for Interior basin Chinook populations and found very few instances of spawning escapements below 50 until recent years (after 1985). The occurrence of annual spawning escapements below 50 is dramatically reduced if the data series is restricted to the pre-1975 period.

We carried out a series of sensitivity analyses relating QET levels to viability curve output parameters to probe the relationship between QET and projected extinction risk (Appendix A). While this analysis does not directly generate a specific number for use as a QET, it is clear from the frequency distributions of annual spawning levels that the proportion of years at low spawning abundance (below QET) increases rapidly as the numerical value of QET is adjusted downwards from 100.

The impact of repeated parent spawning years at such low levels on population productivity is a major uncertainty. This uncertainty contributed to our decision to maintain the QET in our population viability model runs at 50 spawners as a precautionary measure.

A QET value of 50 spawners per year for 4 years is consistent with values used in population viability analyses by the Puget Sound and the Lower Columbia/Willamette TRTs (Ruckelshaus et al. 2004, McElhany et al. 2006). The Puget Sound viability analyses (cited in app. D in McElhany et al. 2003) incorporate a QET value of "…62.5 spawners per year for four years.". The Lower Columbia/Willamette TRT initially used a QET of 50 in the viability analysis described in their initial draft viability report (McElhany et al., 2003). An updated version of their viability report includes an alternative viability modeling approach incorporating a QET that is a function of the relative size (amount of spawning habitat) of a population (McElhany et al. 2006). The new approach translates to a QET of 50 for smaller populations. For larger populations, the new approach would translate to a numerically higher QET, however McElhany et al. (2006) note that although it "[it] is tempting to conclude that since the new QETs are higher

the criteria are more precautionary….the model used in 2003 (PCC) is different from the model in these benchmark curves, making direct comparison problematic." Oregon Coastal TRT incorporates the results from four different types of population viability models. Two alternative QET values are incorporated into each model, with the QET being expressed in terms that are consistent with the structure of the particular model (P. Lawson, pers. comm.). For example, the QET is expressed in terms of a minimum spawner per mile estimate a habitat based population model (Chilcote, 2005). In that particular application, the QET for a population will be a function of the minimum density estimate and the total miles of spawning habitat.

Reproductive Failure Threshold

The population viability models used by the ICTRT also incorporate a Reproductive Failure Threshold (RFT). While the QET is responsive to the number of spawners across a brood cycle, the RFT reflects uncertainty in the production from an extremely low return to the spawning grounds in a single year. If the number of spawners projected for a particular return year is at or below the RFT, production from that brood year is assumed to be 0. We have set the RFT for stream type chinook and steelhead populations to 10 spawners after reviewing updated run reconstruction results for Interior Basins Spring/Summer Chinook populations (Appendix A). Recent escapement levels are well below the documented historical ranges for these populations. Given the uncertainty and potential for increased demographic risks at relatively low population levels, we conducted three modeling exercises to inform the choice of an appropriate RFT value; an analysis of the potential for bias in estimating productivity at low parent spawning number, a simple demographic model of spawning success at low numbers, and an assessment of the relative risk associated with a 'wrong' choice RFT value (Appendix A).

The analysis of potential bias in estimating productivity as a function of spawning numbers indicated that bias in estimated returns from low escapement levels is likely for Interior Columbia data series, and that productivity estimates can be consistently inflated at low parent escapement levels, with the degree of bias increasing substantially for values below 20 spawners. The simple three spawning site model we developed to evaluate the potential impact of demographic effects at low spawner numbers indicated that the effective number of female spawners dropped off rapidly below 10 spawners.

Setting the Reproductive Failure Threshold (see below) at extremely low levels (e.g., less than 10 spawners in our sensitivity analyses) while maintaining the QET at 50 spawners per year over a brood cycle translates to a large increase in the expected proportion of spawning escapements below 50 fish across the 100 year projections. It is highly unlikely that these populations experienced such high proportions of very low spawning escapements historically.

Based on the results of these analyses and the observed returns at low escapements, we selected 10 spawners as a RFT for use in generating viability curves for yearling type chinook salmon and steelhead populations. We maintained the RFT at 50 spawners for Snake River Fall Chinook as a precautionary measure, recognizing the lack of data at very low spawning levels and the relatively large area that spawners can disperse over within the current population.

Minimum Thresholds for Abundance and Productivity

We have incorporated minimum thresholds for abundance into viability curves for application to Interior Columbia populations. Minimum abundance thresholds applied to the viability curves were based on the demographic and genetic rationale provided by McElhany et al. (2000) and reflect estimates of the relative amount of historical spawning and rearing habitat associated with each population. A minimum threshold value at or above 1.0 should also be applied to the population productivity parameter. Given a very high starting abundance, the relatively simple population model used to generate viability curves can, in some circumstances, project relatively low probabilities of extinction for average productivities below 1.0. In those cases the population would, by definition, be in long-term decline.

We incorporated a minimum abundance threshold of 500 spawners into the viability curves for populations in the Basic size category based on genetic and demographic considerations. Populations with fewer than 500 individuals are at higher risk for inbreeding depression and a variety of other genetic concerns (McElhany et al. 2000 and McClure et al. 2003 discuss this topic further). A minimum abundance of 500 spawners would appear adequate for compensatory processes to operate and to maintain within-population spatial structure for smaller Interior Columbia Basin salmon populations. However, for populations that cover big geographic areas with larger intrinsic potential, the ICTRT concluded higher minimum abundance levels were necessary to meet the full range of VSP criteria.

Incrementally higher spawning abundance thresholds were established for the remaining three population size categories (Table 3) We set thresholds for the two larger size categories (Large and Very Large) so that the expected average abundance at threshold levels was equivalent to approximately ½ of the density associated with achieving 500 spawners for a median sized population within the Basic category. Threshold levels for application to populations in the intermediate group were set so as to achieve median spawner densities at approximately half the range between the median population size for Basic and Large population groups. This density level represents a balance between using 500 as a minimum population abundance threshold regardless of the amount of spawning habitat and setting a population level threshold proportional to the amount of potential spawning habitat.). Increased thresholds for larger populations promote achieving the full range of abundance objectives including utilization of multiple spawning areas, avoiding problems associated with low population densities (e.g., Allee effects) and maintaining populations at levels where compensatory processes are functional. Setting the minimum abundance threshold in strict proportion to the estimated amount of potential spawning habitat implied unrealistic precision for each specific population and resulted in very high minimum abundance levels for larger populations.

Table 3. Minimum abundance thresholds by species and historical population size (spawning area) for extant Interior Columbia Basin stream type chinook and steelhead populations. Median weighted area and corresponding spawners per km (calculated as ratio with corresponding threshold) provided for populations in each size category (see appendix B).

Population Size Category	Stream Type Chinook (Upper Columbia Spr, Snake Spr/Sum ESUs)			Steelhead (Upper Columbia, Middle Columbia & Snake River ESUs)		
	Threshold	Median Weighted Area (m X 10,000)	Spawners per KM (weighted)	Threshold	Median Weighted Area (m X 10,000)	Spawners per KM (weighted)
Basic	*500*	23	21.7	*500*	141	3.4
Intermediate	*750*	44	17.1	*1,000*	382	2.6
Large	*1,000*	69	14.4	*1,500*	743	2.0
Very Large	*2,000*	145	13.8	*2,250*	1,175	1.9

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Viability Curves for Interior Basin ESU Populations

We express our abundance and productivity criteria in terms of spawners. Measuring productivity and abundance at the spawning level reflects the cumulative impacts of all factors across the life cycle. The specific viability curves we provide in this report were generated using data from time periods of relatively constant harvest impacts. As a result, assessments based on comparing current spawner based abundance and productivity estimates to these curves effectively assume that recent average harvest rates will continue into the future. In some cases management or recovery strategies will include variable harvest rate strategies. The model we used to generate viability curves can be easily adapted to generate variations on the ESU specific viability curves that incorporate specific harvest rate rule sets.

We have generated specific viability curves for application to populations in each of the listed chinook, steelhead and sockeye ESUs in the Interior Columbia basin. We provide curves corresponding to risk levels of 25%, 5% and 1% over 100 years. Specific input values included age structure along with variance and autocorrelation estimates derived from time series of observed vs. expected brood year productivities (Appendix A). These values were averaged across populations within ESUs to generate representative viability curves (Table 4).

Table 4. Summary of average population input parameters used in generating viability curves for Interior Columbia Basin stream type chinook and steelhead ESUs. Variance and correlation estimates derived from time series of observed vs. expected brood year productivities.

| ESU | No. of trends | Production Parameters | | | Average Age Composition | | | |
| | | ESU Average Values ln (r/s) | | | 3 | 4 | 5 | 6 |
		Variance	Adjusted Var.	Correlation Coefficient				
Snake River Sp/Sum Chinook	13	1.24	0.89	0.53	0.00	0.57	0.43	0.00
Upper Columbia Spring Chinook	3	0.95	0.51	0.68	0.00	0.60	0.40	0.00
Snake River Steelhead	6	0.39	0.25	0.60	0.03	0.60	0.35	0.02
Mid-Columbia Steelhead	12	0.40	0.18	0.74	0.03	0.46	0.43	0.08
Upper Columbia Steelhead [1]	18	0.38	0.20	0.69	0.02	0.38	0.45	0.15
Fall Chinook	1	0.45	0.25	0.67	0.53	0.43	0.04	0.00
Sockeye [2]	1	0.50	0.42	0.41	0.00	0.60	0.40	0.00

[1] Variance and correlation in natural return rates based on average for steelhead populations in Mid-Columbia and Snake River ESUs to avoid potential bias or masking effects of chronic high hatchery levels.
[2] Variance and autocorrelation for Wenatchee River sockeye used as surrogate for Snake River sockeye inputs.

The Willamette-Lower Columbia TRT has developed an alternative viability curved based method, the Population Change Criteria (PCC) approach (WL-LC TRT, 2003). This approach can be adapted to Interior Basin ESU viability curves for application to populations with relatively poor trend data sets.

We encourage the development of metrics at other life stages, including juvenile productivity. Viability curves that incorporate specific measures reflecting survival from spawning to out migrating smolt and from out-migrant to adult return would address a major confounding factor, high year-to-year variability in marine survival rates. Incorporating smolt production measures would also aid in evaluating tributary habitat effects.

Stream Type Chinook and Steelhead

Viability curves were generated for use with two alternative productivity metrics: Return/Spawner and Annual population growth rate (lambda). The first is suitable for situations where detailed age structure and return data are available. Annual population growth rate (lambda) is provided as an alternative for use in situations where only index counts, or other types of counts without age structure are available. An example of a generic ESU viability curve in graphical format is provided in Figure 4. Graphic representations for all of the Interior Basin stream type Chinook and steelhead ESUs are included in Appendix A.

Figure 4a-b: Example of Viability Curves incorporating population size category threshold abundance levels**.**

a. Viability curve for application to populations in BASIC - small size category. Includes minimum average spawner threshold at 500.
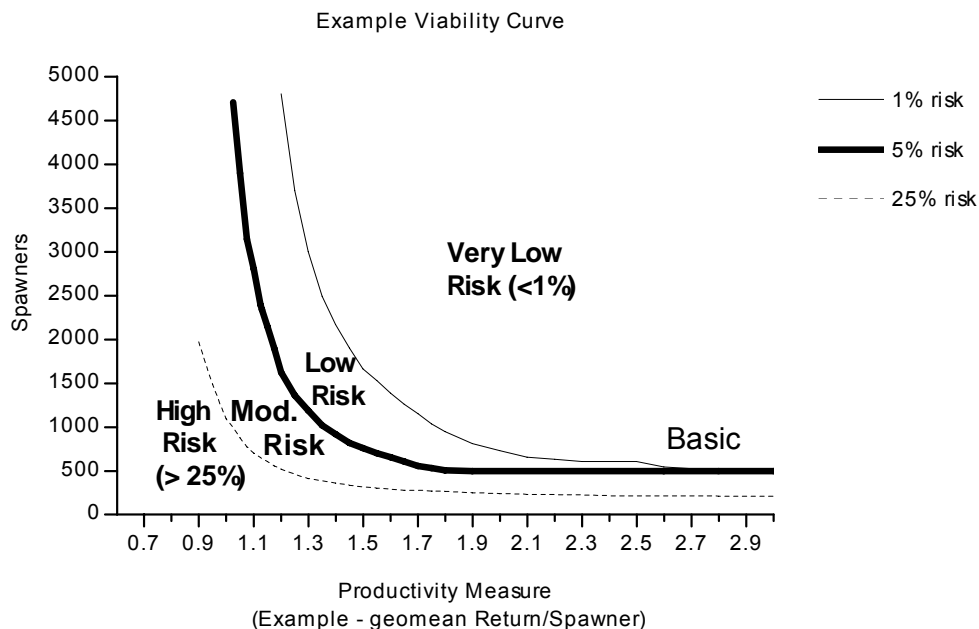
b. Viability Curve including minimum population threshold of 1,000 spawners for use with Large- sized chinook populations.

Table 5a. SNAKE RIVER SPRING/SUMMER CHINOOK. Population Viability curves in tabular format (return per spawner and population growth rate versions). Combinations of abundance and productivity exceeding these combinations would have a projected extinction risk of less than 5% in 100 years, assuming continuation of recent (1978-present) variation in return rates. Spawner/spawner estimates generated using Hockey-Stick recruitment function and average variance (0.89), autocorrelation (0.53) and age structure (0.57 age 4; 0.43 age 5) for populations in the ESU. Population growth rate based estimates generated using average running sums based variance (0.13) for ESU populations.

| Snake River Spr/Sum Chinook Growth Rate (S/S) | Spawner to Spawner Measure | | | | | Population Growth Rate (Lambda) Measure | | | |
| | Minimum Abundance by Population Size Categories | | | | | Minimum Abundance by Population Size Categories | | | |
	Basic	Intermediate	Large	Very Large	Population Growth Rate	Basic	Intermediate	Large	Very Large
1.15	5600	5600	5600	5600	1.02	27000	27000	27000	27000
1.175	4700	4700	4700	4700	1.04	8600	8600	8600	8600
1.2	3900	3900	3900	3900	1.06	4300	4300	4300	4300
1.25	3050	3050	3050	3050	1.08	2000	2000	2000	2000
1.3	2350	2350	2350	2350	1.1	2000	2000	2000	2000
1.35	1950	1950	1950	2000	1.11	1400	1400	1400	2000
1.4	1650	1650	1650	2000	1.12	1000	1000	1000	2000
1.45	1350	1350	1350	2000	1.14	880	880	1000	2000
1.5	1200	1200	1200	2000	1.16	630	750	1000	2000
1.55	1100	1100	1100	2000	1.17	560	750	1000	2000
1.6	970	970	1000	2000	1.18	500	750	1000	2000
1.65	890	890	1000	2000	1.2	500	750	1000	2000
1.7	810	810	1000	2000	1.22	500	750	1000	2000
1.75	760	760	1000	2000	1.24	500	750	1000	2000
1.8	720	750	1000	2000	1.26	500	750	1000	2000
1.9	650	750	1000	2000	1.28	500	750	1000	2000
2	600	750	1000	2000	1.3	500	750	1000	2000
2.1	550	750	1000	2000					
2.2	510	750	1000	2000					
2.3	500	750	1000	2000					
2.4	500	750	1000	2000					
2.5	500	750	1000	2000					
2.6	500	750	1000	2000					

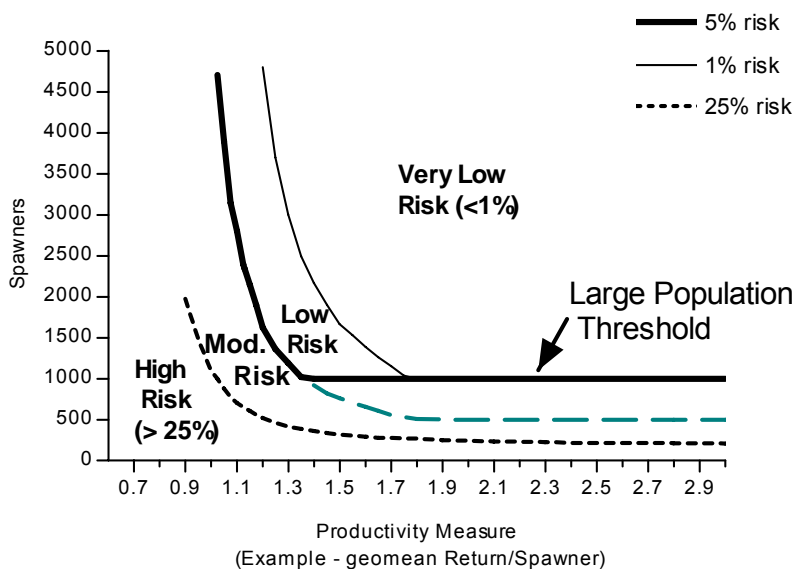Table 5b. UPPER COLUMBIA RIVER SPRING CHINOOK. Population Viability curves in tabular format (return per spawner and population growth rate versions). Combinations of abundance and productivity exceeding these combinations would have a projected extinction risk of less than 5% in 100 years, assuming continuation of recent (1978-present) variation in return rates. Spawner/Spawner estimates generated using Hockey-Stick recruitment function and average variance (0.51), autocorrelation (0.68) and age structure (0.60 age 4; 0.40 age 5) for populations in the ESU. Population growth rate based estimates generated using average running sums based variance (0.13) for ESU populations.

Upper Columbia Spring Chinook Growth Rate (S/S)	Spawner to Spawner Measure — Minimum Abundance by Population Size Categories				Population Growth Rate	Population Growth Rate (Lambda) Measure — Minimum Abundance by Population Size Categories			
	Basic	Intermediate	Large	Very Large		Basic	Intermediate	Large	Very Large
1.35	5400	5400	5400	5400	1.02	48000	48000	48000	48000
1.4	3800	3800	3800	3800	1.04	15400	15400	15400	15400
1.45	3100	3100	3100	3100	1.06	6600	6600	6600	6600
1.5	2700	2700	2700	2700	1.08	3950	3950	3950	3950
1.55	2400	2400	2400	2400	1.1	2300	2300	2300	2300
1.6	2100	2100	2100	2100	1.104	2000	2000	2000	2000
1.65	1850	1850	1850	2000	1.12	1400	1400	1400	2000
1.7	1600	1600	1600	2000	1.14	1050	1050	1050	2000
1.75	1400	1400	1400	2000	1.145	1000	1000	1000	2000
1.8	1300	1300	1300	2000	1.16	830	830	1000	2000
1.9	1100	1100	1100	2000	1.18	580	750	1000	2000
2	950	950	1000	2000	1.2	510	750	1000	2000
2.1	830	830	1000	2000	1.21	500	750	1000	2000
2.2	730	750	1000	2000	1.22	500	750	1000	2000
2.3	670	750	1000	2000	1.24	500	750	1000	2000
2.4	620	750	1000	2000	1.26	500	750	1000	2000
2.5	580	750	1000	2000	1.28	500	750	1000	2000
2.6	550	750	1000	2000	1.3	500	750	1000	2000
2.8	500	750	1000	2000					
3	500	750	1000	2000					
3.2	500	750	1000	2000					

Table 5c. UPPER COLUMBIA RIVER STEELHEAD. Population Viability curves in tabular format (return per spawner and population growth rate versions). Combinations of abundance and productivity exceeding these combinations would have a projected extinction risk of less than 5% in 100 years, assuming continuation of recent (1978-present) variation in return rates. Spawner/Spawner estimates generated using Hockey-Stick recruitment function and average variance (0.20), autocorrelation (0.69) and age structure (0.02 age 3; 0.38 age 4; 0.45 age 5; 0.15 age 6) for Interior Basin steelhead population trend data sets. Population growth rate based estimates generated using average running sums based variance (0.16) for ESU populations.

| Upper Columbia Steelhead Growth Rate (S/S) | Spawner to Spawner Measure | | | | Population Growth Rate (Lambda) Measure | | | | |
| | Minimum Abundance by Population Size Categories | | | | | Minimum Abundance by Population Size Categories | | | |
	Basic	Intermediate	Large	Very Large	Population Growth Rate	Basic	Intermediate	Large	Very Large
1	6600	6600	6600	6600	1.02	48000	48000	48000	48000
1.025	4700	4700	4700	4700	1.04	15400	15400	15400	15400
1.05	3800	3800	3800	3800	1.06	6600	6600	6600	6600
1.075	2850	2850	2850	2850	1.08	3950	3950	3950	3950
1.1	2150	2150	2150	2250	1.1	2300	2300	2300	2300
1.125	1800	1800	1800	2250	1.104	2000	2000	2000	2250
1.13	1650	1650	1650	2250	1.12	1400	1400	1500	2250
1.15	1450	1450	1500	2250	1.14	1050	1050	1500	2250
1.175	1200	1200	1500	2250	1.145	1000	1000	1500	2250
1.2	980	1000	1500	2250	1.16	830	1000	1500	2250
1.25	750	1000	1500	2250	1.18	580	1000	1500	2250
1.3	580	1000	1500	2250	1.2	510	1000	1500	2250
1.35	500	1000	1500	2250	1.21	500	1000	1500	2250
1.4	500	1000	1500	2250	1.22	500	1000	1500	2250
1.45	500	1000	1500	2250	1.24	500	1000	1500	2250
1.5	500	1000	1500	2250	1.26	500	1000	1500	2250
1.55	500	1000	1500	2250	1.28	500	1000	1500	2250
1.6	500	1000	1500	2250	1.3	500	1000	1500	2250
1.65	500	1000	1500	2250					
1.7	500	1000	1500	2250					
1.75	500	1000	1500	2250					

Table 5d. SNAKE RIVER STEELHEAD. Population Viability curves in tabular format (return per spawner and population growth rate versions).). Combinations of abundance and productivity exceeding these combinations would have a projected extinction risk of less than 5% in 100 years, assuming continuation of recent (1978-present) variation in return rates. Spawner/Spawner estimates generated using Hockey-Stick recruitment function and average variance (0.25), autocorrelation (0.60) and age structure (0.03 age 3; 0.60 age 4; 0.35 age 5; 0.02 age 6) for populations in the ESU. Population growth rate based estimates generated using average running sums based variance (.19) for ESU populations.

	Spawner to Spawner Measure					Population Growth Rate (Lambda) Measure			
Snake River Steelhead Growth Rate (S/S)	Minimum Abundance by Population Size Categories				Population Growth Rate	Minimum Abundance by Population Size Categories			
	Basic	Intermediate	Large	Very Large		Basic	Intermediate	Large	Very Large
1	4300	4300	4300	4300	1.02	27000	27000	27000	27000
1.025	3150	3150	3150	3150	1.04	8650	8650	8650	8650
1.05	2300	2300	2300	2300	1.06	4300	4300	4300	4300
1.075	1800	1800	1800	2250	1.08	2000	2000	2000	2250
1.1	1400	1400	1500	2250	1.1	1950	1950	1950	2250
1.125	1200	1200	1500	2250	1.11	1400	1400	1500	2250
1.13	1100	1100	1500	2250	1.12	1000	1000	1500	2250
1.15	940	1000	1500	2250	1.14	880	1000	1500	2250
1.175	830	1000	1500	2250	1.16	630	1000	1500	2250
1.2	720	1000	1500	2250	1.17	560	1000	1500	2250
1.25	550	1000	1500	2250	1.18	500	1000	1500	2250
1.3	500	1000	1500	2250	1.2	500	1000	1500	2250
1.35	500	1000	1500	2250	1.22	500	1000	1500	2250
1.4	500	1000	1500	2250	1.24	500	1000	1500	2250
1.45	500	1000	1500	2250	1.26	500	1000	1500	2250
1.5	500	1000	1500	2250	1.28	500	1000	1500	2250
1.55	500	1000	1500	2250	1.3	500	1000	1500	2250
1.6	500	1000	1500	2250					
1.65	500	1000	1500	2250					
1.7	500	1000	1500	2250					
1.75	500	1000	1500	2250					
1.8	500	1000	1500	2250					
1.9	500	1000	1500	2250					

Table 5e. MID-COLUMBIA RIVER STEELHEAD. Population Viability curves in tabular format (return per spawner and population growth rate versions).). Combinations of abundance and productivity exceeding these combinations would have a projected extinction risk of less than 5% in 100 years, assuming continuation of recent (1978-present) variation in return rates. Spawner to spawner estimates generated using Hockey-Stick recruitment function and average variance (0.18), autocorrelation (0.74) and age structure (0.03 age 3; 0.46 age 4; 0.43 age 5; 0.04 age 6) for populations in the ESU. Population growth rate based estimates generated using average running sums based variance (0.17) for ESU populations.

| Middle Columbia Steelhead Growth Rate (S/S) | Spawner to Spawner Measure | | | | | Population Growth Rate (Lambda) Measure | | | |
| | Minimum Abundance by Population Size Categories | | | | Population Growth Rate | Minimum Abundance by Population Size Categories | | | |
	Basic	Intermediate	Large	Very Large		Basic	Intermediate	Large	Very Large
1.1	5650	5650	5650	5650	1.02	48000	48000	48000	48000
1.125	4200	4200	4200	4200	1.04	15400	15400	15400	15400
1.13	3900	3900	3900	3900	1.06	6600	6600	6600	6600
1.15	3300	3300	3300	3300	1.08	3950	3950	3950	3950
1.175	2500	2500	2500	2500	1.1	2300	2300	2300	2300
1.2	2050	2050	2050	2250	1.104	2000	2000	2000	2250
1.25	1550	1550	1550	2250	1.12	1400	1400	1500	2250
1.3	1200	1200	1500	2250	1.14	1050	1050	1500	2250
1.35	1000	1000	1500	2250	1.145	1000	1000	1500	2250
1.4	800	1000	1500	2250	1.16	830	1000	1500	2250
1.45	660	1000	1500	2250	1.18	580	1000	1500	2250
1.5	570	1000	1500	2250	1.2	510	1000	1500	2250
1.55	520	1000	1500	2250	1.21	500	1000	1500	2250
1.6	500	1000	1500	2250	1.22	500	1000	1500	2250
1.65	500	1000	1500	2250	1.24	500	1000	1500	2250
1.7	500	1000	1500	2250	1.26	500	1000	1500	2250
1.75	500	1000	1500	2250	1.28	500	1000	1500	2250
1.8	500	1000	1500	2250	1.3	500	1000	1500	2250
1.9	500	1000	1500	2250					
2	500	1000	1500	2250					
2.1	500	1000	1500	2250					

Snake River Fall Chinook

Snake River fall chinook exhibit important life history differences from stream type chinook and steelhead. Snake River fall chinook spawned primarily in large mainstem reaches and the dominant juvenile life history pattern was for subyearling migration. We calculated a viability curve for Snake River fall chinook (Figure 5) following the same analytical steps we applied to stream type chinook and steelhead ESUs.

We established a minimum abundance threshold for fall chinook consistent with the general abundance/productivity objectives summarized in the July 2003 ICTRT Viability draft report. We are recommending a minimum abundance threshold of 3,000 natural origin spawners for the extant Snake River fall chinook population. No fewer than 2,500 of those natural origin spawners should be distributed in mainstem Snake River habitat.
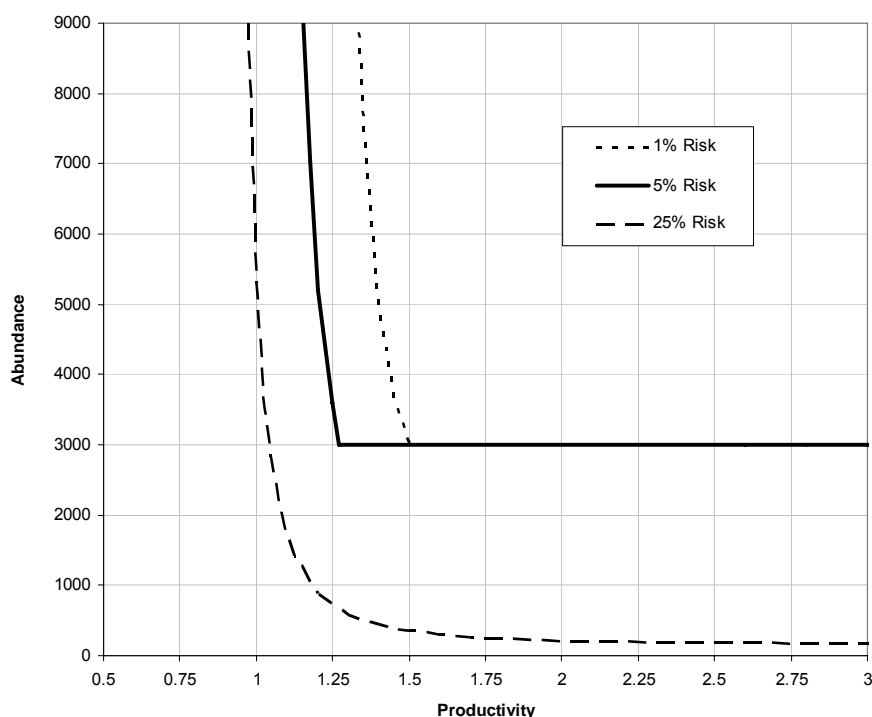
Figure 5. Viability curves for Snake River Fall chinook.

Snake River Sockeye

We generated two sets of curves for application to potential Stanley Lake Basin sockeye populations (Figures 6 a-b); these differ in their minimum abundance thresholds. More detailed descriptions of the relative size categories for Interior Columbia River Basin sockeye populations are provided in Appendix B. The Stanley Basin Lakes are relatively small compared to other lake systems that historically supported sockeye production in the Columbia Basin. Stanley

Lake is assigned to the smallest size category along with Pettit and Yellowbelly Lakes. Redfish Lake and Alturas Lake fall into the next size category – intermediate. We adapted the recovery abundance levels recommended by the Snake River Recovery Team (Bevan, et al. 1994) as minimum abundance thresholds. We set the minimum spawning abundance threshold at 1,000 for the Redfish and Alturas Lake populations (intermediate category), and at 500 for populations in the smallest historical size category (e.g., Stanley Lake). We used a run reconstruction of Lake Wenatchee sockeye as the basis for a representative set of variance and autocorrelation input values along with average age structure from historical Redfish Lake data (Appendix A).

Figure 6a-b. Viability curves for application to Snake River sockeye lake populations. A) Redfish Lake and Alturas Lake (Intermediate). B) small lake populations (Stanley Lake). Age structure used was 60% age 4 and 40% age 5 adult returns. Adjusted variance (variance unexplained by autocorrelation) and autocorrelation parameters (derived from Lake Wenatchee data) were 0.42 and 0.41, respectively.

a)
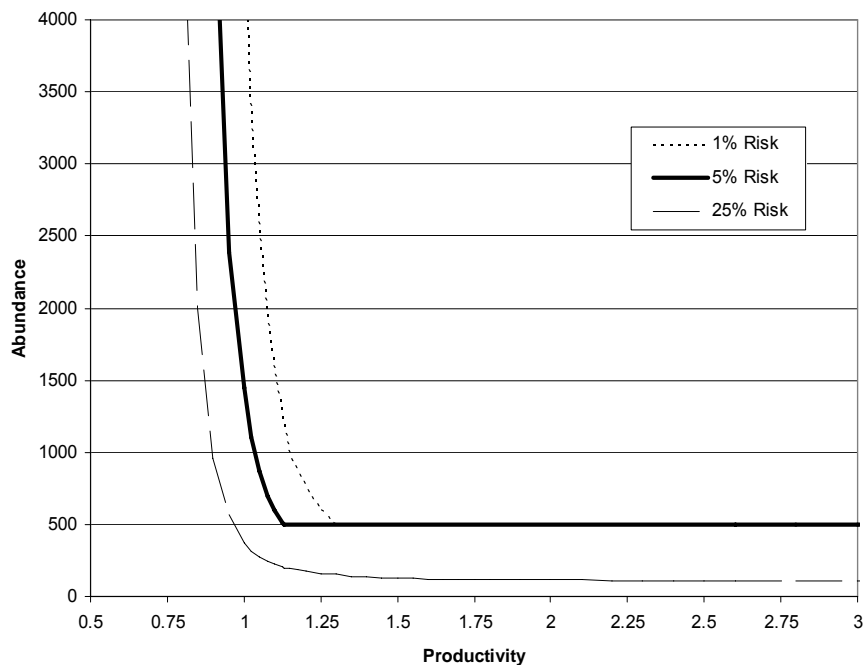
b)
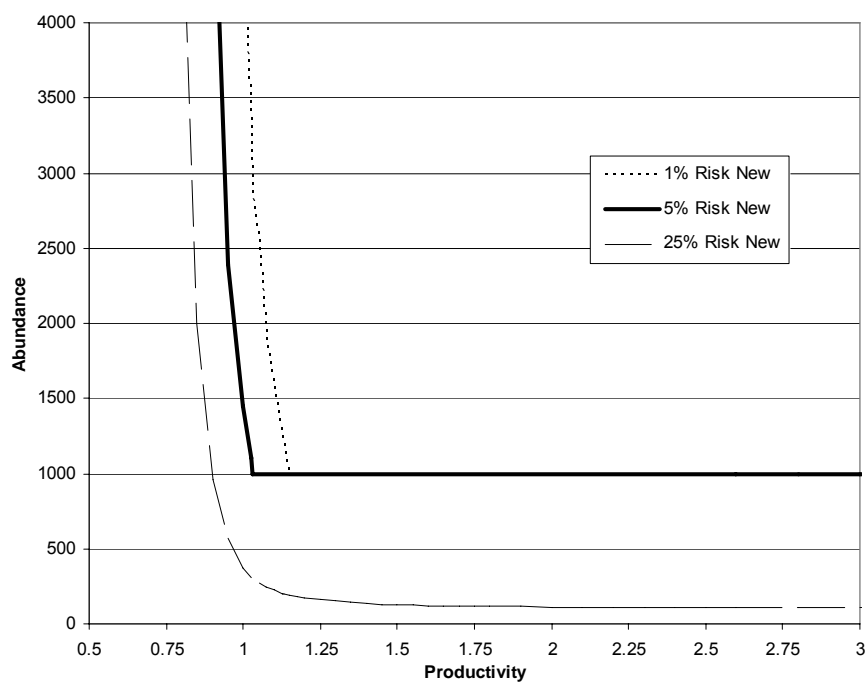
Evaluating Population Status vs. Viability Curves

The underlying objective of the comparison of current status against a viability curve is to evaluate the relative likelihood that natural origin fish in the population of interest is capable of being self-sustaining. Comparing current status against the appropriate viability curve requires a measure of recent natural origin abundance and a measure of recent average intrinsic productivity. Intrinsic productivity is the expected production rate (expressed as a ratio of returns to spawn in future years vs. parent spawning numbers) experienced when spawner densities are low and compensation is not reducing productivity. The recent abundance metric must be measured in terms of spawners of natural origin. The measure of recent average productivity should reflect natural origin returns produced from the total number of fish directly contributing to spawning in the parental year. Hatchery origin natural spawners are counted as parents in the productivity calculations, and their natural origin offspring are counted as recruits and become natural origin parents in the next generation. In populations where a direct estimate of the relative productivity of hatchery origin spawners is available, the estimate of intrinsic productivity should be adjusted to reflect the rate associated with natural origin spawners.

Simple measures of current intrinsic productivity (both return/spawner and population growth rate metrics) can be influenced by the relative density of parent spawners. Most populations of listed Interior Columbia Basin stream type chinook and steelhead are currently at relatively low levels of abundance. As a result, adjustments to separate out the effects of carrying capacity are not necessary. However, as stock approach rebuilding target levels, direct estimates of intrinsic productivity can be affected by carrying capacity. There are options for addressing carrying capacity effects. Population growth rate approaches could employ threshold average spawning levels – if recent average total escapements exceed levels associated with carrying capacity effects, the expected population growth rate targets could be referenced to population maintenance (e.g., low likelihood average population growth rate is less than 1.0). Return per spawner series can be filtered, return per spawner pairs in which the parent escapements exceed a threshold associated with carrying capacity can be left out of the calculation of a recent average productivity.

The ICTRT has developed a relatively simple non-parametric approach for estimating productivity parameters for Interior Columbia salmon and steelhead populations. We describe and apply that approach in a separate report summarizing current status for Interior Columbia ESUs and their component populations (ICTRT in progress). In most cases, data used to evaluate current status will be based on a relatively limited number of years. Uncertainty levels and bias in parameter estimates can be very large. When sufficient data were available, we used a non-parametric approach to generate estimates of intrinsic productivity and the number of spawners associated with maximum production. We incorporated those estimates into a function in the form of a hockey stick recruitment function to generate viability curves.

We recognize that fitted stock recruit curves (e.g., Ricker, Hockey stick or Beverton Holt) are commonly used to estimate population productivity characteristics and as the basis for population viability analyses. There is substantial potential for error or systematic bias in estimates generated using curve fitting techniques, especially when a data series is relatively short and highly variable (Hilborn & Walters, 1992). Approaches to risk assessment based on

empirical curve fitting should explicitly incorporate methods to reduce the impact of error and bias. In some cases, error or bias can be reduced by the choice of an appropriate statistical framework (e.g., Myers & Mertz, 1998, Mackinson et al. 1999, Michielsens & McAllister, 2004) or by incorporating independent variables that account for components of the overall variability in annual return rates (e.g., Morris & Doak, 2002).

Addressing Uncertainty in Assessing Current Status

Estimates of the current abundance and productivity of a population were based on sampling data and therefore were subject to some level of statistical uncertainty. The level of uncertainty, especially for the estimated productivity of a population, had a substantial impact relative to achieving targeted risk levels. The number of years included in the measures of recent abundance and productivity were a function of the specific methods used in generating measurements, the form of the criteria and the variance in annual return rates. Previous attempts to set recovery objectives (e.g., Bevan et al., 1995; Ford et al. 2001, McElhany et al., 2003) recommended minimum time series ranging in length from 8 to 20 years.

Sampling Induced Error

Preliminary sensitivity analyses indicate that directly incorporating a measure of the relative uncertainty in estimates of current productivity and abundance can reduce the potential for concluding that a population is at low risk when the 'true' risk level is actually high (type II error). Therefore, we recommend that current status estimates for comparison against the appropriate viability curve should include an adjustment based on the standard errors associated with point estimates of productivity and abundance. Preliminary evaluations indicate that the results are particularly sensitive to the estimate of intrinsic productivity.

We have evaluated three reasonable alternatives for buffering comparisons of current abundance and productivity for a population against the corresponding ICTRT risk metrics (Table 6). A more detailed explanation of these alternatives is included in Appendix A. We provide these examples as possible options to be considered in the recovery planning process, as well as to illustrate the relative sensitivity of status metrics to year to year variability and sampling uncertainties. Ultimately, choices regarding the treatment of uncertainty in decision-making include policy considerations.

Table 6. Alternative approaches for directly incorporating uncertainty into quantitative assessments of current status. Option A - simple probability based buffer, Option B1 two variations on a dual test approach designed to minimize the chance that the risk level being estimated is actually HIGH.

| Option	Very Low Risk	Low Risk	Moderate Risk
A. Simple Probability Buffer	No less than **an 85% (approx. 1 stnd. error)** chance of being above the **1**% viability curve.	No less than **an 85% (approx. 1 stnd. error)** chance of being above the **5**% viability curve.	No less that a 50% probability of being above the **25%** viability curve
B.1 Dual Comparison: tolerance test to minimize chance that risk is actually High	No less that a 50% probability of being above the **1%** viability curve AND No more than a **1 in 100 (1%)** chance that the actual risk level exceeds **25%**	No less that a 50% probability of being above the **5%** viability curve AND No more than **a 1 in 20 (5%)** chance that the actual risk level exceeds **25%**	No less that a 50% probability of being above the **25%** viability curve
B.2 Dual Comparison: More precautionary tolerance test to minimize chance that risk is actually High	No less that a 50% probability of being above the **1%** viability curve AND No more than a **1 in 100 (1%)** chance that the actual risk level exceeds **10%**	No less that a 50% probability of being above the **5%** viability curve AND No more than **a 1 in 20 (5%)** chance that the actual risk level exceeds **10%**	No less that a 50% probability of being above the **25%** viability curve
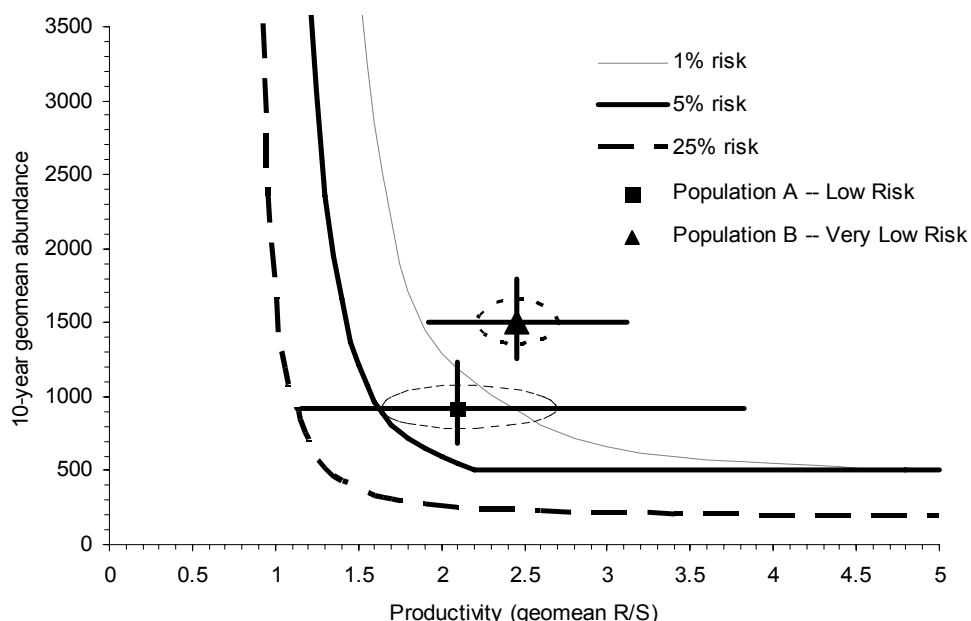
Figure 7. Evaluating the abundance and productivity of a population relative to the Viability Curve. Triangle and box symbols are point estimates of abundance and productivity for example populations. Ovals represent 1 standard error about mean values. Straight lines indicate 95% confidence limits on estimated abundance and productivity. Population A would be rated at Low Risk with respect to abundance/productivity, while Population B would get a Very Low Risk rating.

In general, all the analyzed options for treating uncertainty would result in a higher overall target (increasing the certainty that the population would "truly" be at or above the viability curve). Populations with higher variability require the greatest increases in the target, regardless of the option chosen. For a given variability level, the simple probabilistic buffer typically requires the greatest increase in the target, although there is some interaction with the level of variability of the population. Unlike the lower and moderately variable populations, a highly variable population would require a greater target to meet a stringent dual comparison than a simple probabilistic buffer. The following example illustrates the potential effect of using the alternative approaches for directly incorporating uncertainty associated with productivity estimates (Figure 8). The example is based upon the viability curves for a Very Large population within the Upper Columbia Spring Chinook ESU and includes a range of sample standard errors reflecting the levels calculated from recent data series for interior basin populations. These examples are based on an assumption that variation in mean productivity and abundance is multiplicative, following a lognormal distribution.
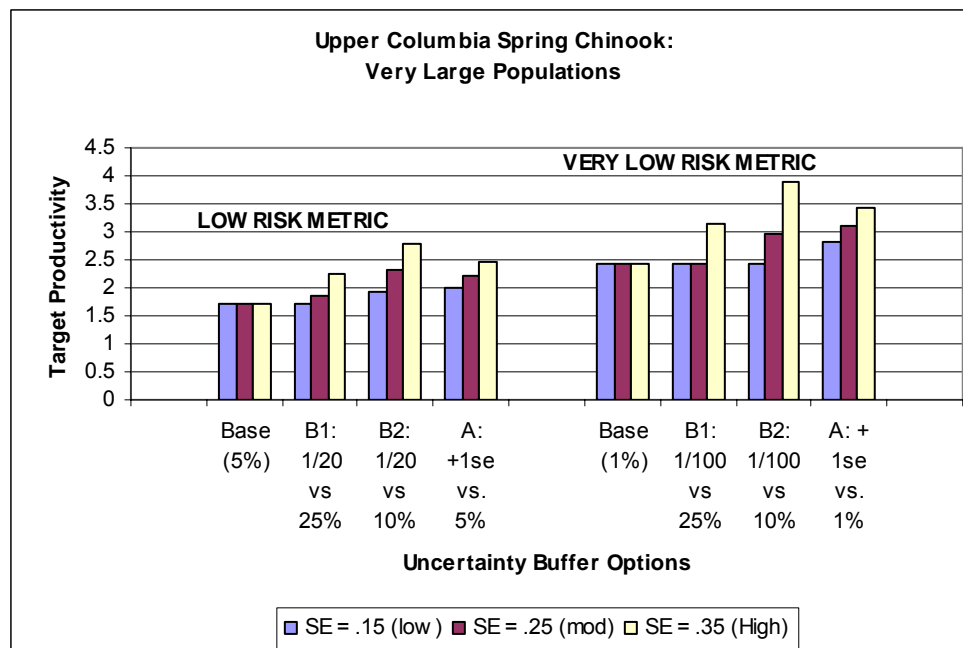
Figure 8. Example of the effects of alternative uncertainty buffers on the minimum productivity required at threshold abundance levels.

Spatial Structure and Diversity

Spatial structure concerns a population's geographic distribution and the processes that affect the distribution (McElhany et al. 2000). This distribution can affect population viability in several ways. For example, populations with a restricted distribution are more subject to loss due to a fine-scale environmental event (such as a single landslide) than populations with a more widespread or complex spatial structure (Isaak et al. 2003, Kallimanis et al. 2005). In addition, spatial structure can influence patterns of gene flow both within the population and between populations. It can thus affect a population's adaptation to local environmental conditions (Whiteley et al. 2004). Spatial structure's impact on extinction risk therefore spans both population dynamics and evolutionary processes (Morita and Yamamoto; Schrott et al. 2005).

Population-level diversity is similarly important for long-term persistence. Environments continually change due to natural process and anthropogenic influences. Populations exhibiting greater diversity are generally more resilient to these environmental changes in the short and long term. Phenotypic diversity, which includes variation in morphology and life history traits, allows more diverse populations to use a wider array of environments and protects populations against short-term temporal and spatial environment changes. Underlying genetic diversity provides the ability to survive long-term changes in the environment. Diversity criteria help ensure the preservation of the underlying genetic resources necessary for a population to fully exploit existing ecological opportunities, adapt to future environmental changes, or simply maintain a sustainable status. The emphasis must be on preservation, because once lost genetic variation is effectively gone forever (Riddell 1993). Riddell (1993) presented 10 principles for conserving diversity, primarily through the conservation of distinct reproductive groups. The focus of this strategy is to "manage Pacific salmon from the premise that localized spawning populations are genetically different, and valuable to the long term production of this resource." Populations and subpopulations (demes) were viewed as standard units for preserving diversity. The conservation of diversity could be achieved by "maximizing the spatial and temporal distribution of demes …maintaining populations with unique genetic traits or, genetic traits of importance, [or] maintaining populations occupying atypical habitats or expressing unusual phenotypic traits."

McElhany et al (2000) provide a number of additional guidelines for the spatial structure and diversity of viable salmonid populations that consider these principles. Specifically, their guidelines suggest that for spatial structure: a) habitat patches should not be destroyed faster than they are naturally created; b) natural rates of straying among subpopulations should not be substantially increased or decreased by human actions; c) some habitat patches should be maintained that appear to be suitable or marginally suitable, but currently contain no fish; and d) source subpopulations should be maintained. For diversity, they indicate that the important principles include: a) human-caused factors such as habitat changes, harvest pressures, artificial propagation, and exotic species introduction should not substantially alter variation in traits such as run timing, age structure, size, fecundity, morphology, behavior, and molecular genetic characteristics; b) natural processes of dispersal should be maintained. Human-caused factors should not substantially alter the rate of gene flow among populations; c) natural processes that

cause ecological variation should be maintained. For both these parameters, a recommendation that uncertainty be accounted for in status evaluations is also included.

The ICTRT has used the general guidelines presented by McElhany et al. (2000) and Riddell (1993) to develop criteria with which to assess the robustness of a population. Because the spatial structure and diversity guidelines outlined are broadly overlapping (see above.), we consider these two parameters jointly. We consider all our criteria to be based on the conditions expressed by natural-origin fish. Finally, we follow the suggestion of McElhany et al. (2000) to use historical spatial structure and diversity as a default benchmark, since neither the precise role that diversity plays in salmonid population viability nor the relationship of spatial processes to viability are well-understood.

Interior Columbia Spatial Structure and Diversity Applications

Our viability criteria for spatial structure and diversity provide a measure of the status of a population. They address specific components of these parameters (or processes that affect these parameters), and thus also provide guidance for recovery actions to restore and/or preserve those populations. There is a good deal of uncertainty in many aspects of our spatial structure and diversity criteria, not least of which is due to the lack of well-developed theory about the impact of these parameters on population and meta-population viability. These criteria were developed to provide a consistent structure in which to consider spatial structure and diversity, even in those cases when expert judgment must be used. They are consistent with current understanding of these factors. As additional data and information become available, they may change – either in the values of the criteria associated with risk levels, or in the definition of the metrics themselves. If alternative approaches or data are available, they can and should be considered in a spatial structure and diversity assessment. However, the *intent* of our metrics is to identify those factors that have the potential to affect the long-term persistence of the population, and these principles should be preserved.

Structure of our Spatial Structure and Diversity Criteria

We express spatial structure and diversity viable salmonid population (VSP) guidelines in a hierarchical format that outlines the goals, mechanisms to achieve those goals, and examples of factors to be considered in assessing a population's risk level. We developed some examples of scenarios leading to various levels of risk. In this document, we use that structure to present metrics (along with examples) appropriate for assessing population status with respect to each mechanism, and ultimately with respect to our biological goals. For clarification, we present the following definitions:

G*oals* are the biological or ecological objectives that spatial structure and diversity criteria are intended to achieve. We have identified two primary goals:

1. Maintaining natural rates and levels of spatially-mediated processes. This goal serves to minimize the likelihood that populations will be lost due to local catastrophe, to maintain natural rates of recolonization within the population and between populations, and to maintain other population functions that depend on the spatial

arrangement of the population.

2. <u>Maintaining natural patterns of variation.</u> This goal serves to ensure that populations can withstand environmental variation in the short and long terms.

Mechanisms are biological or ecological processes that contribute to achieving those goals (e.g., gene flow patterns affect the distribution of genotypic and phenotypic variation in a population).

Factors are characteristics of a population or its environment that influence mechanisms (e.g., gaps in spawning distribution affect patterns of gene flow, which then affect patterns of genotypic and phenotypic variation). In some cases the same factor can affect more than one mechanism or goal. The distribution of spawning areas in a branched vs. a linear system, for example, can affect both patterns of gene flow *and* the patterns of spatially mediated processes, such as catastrophes.

Metrics are measured and assessed at regular intervals to determine whether a population has achieved goals, or to evaluate its current risk level. Each factor has one or more metrics associated with it.

Criteria are specific values of metrics that indicate different risk levels.

We summarize the association between our defined goals, mechanisms, factors and metrics in Table 7. When a factor affects more than one mechanism or goal, we listed it under the mechanism for which it is most directly relevant.

Table 7. Organization of goals, mechanisms, factors and metrics for spatial structure and diversity risk ratings.

Goal	Mechanism	Factor	Metrics
A. Allowing natural rates and levels of spatially-mediated processes.	1. Maintain natural distribution of spawning areas.	a. number and spatial arrangement of spawning areas.	Number of MaSAs, distribution of MaSAs, and quantity of habitat outside MaSAs.
		b. Spatial extent or range of population	Proportion of historical range occupied and presence/absence of spawners in MaSAs
		c. Increase or decrease gaps or continuities between spawning areas.	Change in occupancy of MaSAs that affects connectivity within the population.
B. Maintaining natural levels of variation.	1. Maintain natural patterns of phenotypic and genotypic expression.	a. Major life history strategies.	Distribution of major life history expression within a population
		b. Phenotypic variation.	Reduction in variability of traits, shift in mean value of trait, loss of traits.
		c. Genetic variation.	Analysis addressing within and between population genetic variation.
	2. Maintain natural patterns of gene flow.	a. Spawner composition.	(1) Proportion of natural spawners that are unnatural out-of ESU spawners.
			(2) Proportion of natural spawners that are unnatural out-of MPG spawners.
			(3) Proportion of hatchery origin natural spawners derived from a within MPG brood stock program, or within population (not best practices) program
			(4) Proportion of hatchery origin natural spawners derived from a local (within population) broodstock program using best management practices.
	3. Maintain occupancy in a natural variety of available habitat types.	a. Distribution of population across habitat types.	Change in occupancy across ecoregion types
	4.Maintain integrity of natural systems.	a. Selective change in natural processes or impacts.	Ongoing anthropogenic activities inducing selective mortality or habitat change within or out of population boundary

Distribution and Occupancy

Several of our metrics relevant for spatial structure and diversity are dependent upon a comparison between historical conditions or distribution and current distribution.

- *Historical or potential distribution.* We used our analysis of intrinsic potential (Appendix B) as our hypothesis of potential or historically-occupied areas. Specifically, we assumed that areas rated "high" or "moderate" in that analysis were occupied, for purposes of our spatial structure and diversity assessments.

- *Current distribution or occupancy.* Occupied areas are those in which two or more redds from natural origin spawners have been observed in all years of the most recent brood cycle (i.e. the most recent generation) and have been observed for at least half of the most recent three brood cycles (approximately 15 years for steelhead and chinook). A MiSA is regarded as occupied when it has two or more redds present over the previously defined time periods. A MaSA is regarded as occupied when it has two or more redds within BOTH the upper and lower half of the weighted spawning area within that MaSA over the previously defined time periods. Natural origin offspring of hatchery fish are included in current distribution or occupancy.

We recognize that data may not be available at the appropriate scale to thoroughly evaluate all populations against the range of metrics described below. For immediate needs, we assess current occupancy using agency-defined species distribution. Future monitoring should be structured to assess occupancy more rigorously.

Habitat that is currently accessible and suitable should not be considered occupied unless occupancy criteria are met within the habitat. We regard the current vs. historical distribution comparison to be critical for assessing population status, in which we determine which aspects of the population's demographic and population-level characteristics put it at risk. However, we recognize that a comparison of areas that could be occupied to historical and current distribution is an important component of a limiting factors analysis, in which the aim is to determine the factors that need to be altered in the population's environment to improve its status.

Addressing Uncertainty in Spatial Structure and Diversity Assessments

An assessment of spatial structure and diversity at the population level requires consideration of a range of factors and the certainty of the information used to assess risk.

Information certainty needs to be considered in the risk assignment for SS/D criteria. The confidence in the assigned risk level is directly related to the certainty in the data and information used to assess risk. We recommend a precautionary approach, raising the assigned risk to a higher level in circumstances where there is a high level of uncertainty inherent in the data or information available for a particular metric.

Uncertainties associated with the SS/D criteria (individually as well as in aggregate) can be classified into the following categories and subcategories:

A. Data quality for a particular metric for the population of interest

    a. Completeness of spatial and temporal coverage within a year

    b. Length of the time series of the metric

    c. Consideration of precision and accuracy for the metric

B. Surrogate information for a metric

    a. Information for a specific metric from a population deemed to have similar characteristics

    b. Using other information from surrogate metrics

C. No data or information available for a metric

There is considerable variation across ESUs, and among populations within ESUs, in terms of the particular categories and the relative level of potential uncertainty effects. Metrics for which there are no data(lowest level of certainty) are presently assigned a moderate level of risk. Risk levels for metrics for which the data are assigned high or moderate certainty should not be adjusted. When the certainty is low the risk rating should be increased by one level. We provide the following guidelines to aid addressing different levels of uncertainty that may be encountered in evaluating populations against specific SS/D metrics.

High level of certainty, for a specific metric, can be achieved when there is specific information for the population of interest and the data is spatially and temporally complete for each year in the time series. In addition, the time series must be of adequate length (see criteria and occupancy descriptions) and the data must have high level of precision and accuracy as it relates to the metric of interest.

Moderate level of certainty, for a specific metric, is assigned when there is at least surrogate information from a population deemed to have similar characteristics or surrogate metric information. The surrogate information should be spatially and temporally complete for each year in the time series, the time series must be of adequate length, and the data must have high level of precision and accuracy as it relates to the metric of interest.

An additional way of assigning a moderate level of certainty, for a specific metric, is when information for the population of interest does not meet the conditions described for the high level of certainty for one of the following characteristics: spatial and temporal completeness; time series length; or precision and accuracy.

Low level of certainty, for a specific metric, is assigned when surrogate information does not meet the conditions described for the high level of certainty for one of the following characteristics: spatial and temporal completeness; time series length; or precision and accuracy.

An additional way of assigning a low level of certainty, for a specific metric, is when information for the population of interest does not meet the conditions described for the high level of certainty for two or more of the following characteristics: spatial and temporal completeness; time series length; or precision and accuracy.

Spatial Structure and Diversity Criteria

Goal A: Allowing natural rates and levels of spatially-mediated processes

Spatially-mediated processes are those biological processes, such as gene flow, demographic exchange, local extirpation and recolonization that are influenced by the distribution and spatial organization of the population on the landscape. These processes are important both for mitigating risk of loss to local catastrophes and for maintaining normative levels of exchange among populations. We have developed an analysis of landscape intrinsic potential, or suitability for salmonid spawning (Appendix C); we use this analysis to characterize "natural" or "historical" distributions for this goal. If there is reason to believe that this hypothesis of distribution is in error, alternative historical distributions can be used, but the basis for those needs to be documented.

Mechanism A.1. Maintain natural distribution of spawning areas

We identified three factors that we consider under this mechanism:

1. Number and spatial arrangement of spawning areas

2. Current spatial range compared to historical spatial range

3. Change in gaps or continuities between spawning areas

Each of these factors addresses a different aspect of population distribution. The first addresses the inherent risk associated with different population configurations (e.g. linear vs. branched) in recognition that extinction risk is mitigated by physical separation of spawning habitats (Kallimanis et al. 2005). The second considers shrinkage or contraction of the distribution at its edges or extremes. These areas may be particularly important for maintaining connectivity with other populations (e.g. Dunham et al. 1997). The third factor considers changes of distribution within the population.

Factor A.1.a. Number and spatial arrangement of spawning areas

This metric addresses the inherent risk to the population owing to its natural configuration. Our criteria depend on the current number and arrangement of occupied MaSAs and other spawning habitat (Table 8). The dendritic pattern of rivers has been shown to have sometimes profound effects on extinction risk (Fagan 2002).

Table 8. Factor A.1a: Criteria describing risk levels associated with the number and spatial arrangement of occupied spawning areas.

Factor/metric	Pop. Group	Risk level			
		Very Low	Low	Moderate	High
Factor: Number and spatial arrangement of spawning areas		4 or more MaSAs in a non-linear configuration; or	2-3 MaSAs in a non-linear configuration separated by 1 or more confluences	2 or more MaSAs in linear configuration; or	≤ 1 MaSA
Metric: Number of MaSAs, distribution of MaSAs, and quantity of habitat outside MaSAs	A,B,C,D	3 MaSAs in a non-linear configuration plus one or more branches or MiSAs (outside of a MaSA) that sum to greater than 75% of the minimum habitat quantity of a MaSA (1 MaSA=100,000 m2 for spring/summer chinook salmon and 250,000 for steelhead)		1 MaSA plus one or more branches of MiSAs (outside of a MaSA) that sum to greater than 75% of the minimum habitat quantity of a MaSA or 1 MaSA with weighted intrinsic habitat quantity equal to or greater than the minimum needed for two MaSAs	

Factor A.1.b. Spatial extent or range of population

Reductions in the range of habitat used by a particular population can affect its vulnerability to local catastrophes. In addition, changes across significant habitat conditions (such as elevation) can affect life history or morphological diversity within a population (Frissell 1986). Finally, any change in range that increases or decreases the distance among populations may alter exchange of individuals between populations, hampering the exchange of genetic materials within an MPG and/or an ESU, and altering the likelihood of recolonization of extirpated areas (e.g. Bentzen Et al. 2001). We use occupancy of MaSAs across habitat conditions as our metric, reflecting the risk imposed by the current distribution of the population. (Table 9).

Table 9. Factor A.1.b. Criteria describing risk levels associated with spatial extent or range of population.

Factor/ Metrics	Pop. Group	Risk Level			
		Very Low	Low	Moderate	High
Factor: Spatial extent or range of population	A	Not attainable	All historical MaSAs occupied	50% or more of historical MaSAs occupied.	Less than 50% of historical MaSAs occupied.
Metrics: Occupancy of MaSAs across likely historical habitat conditions	B,C,D	Current spawning distribution mirrors historical (greater than 90% of historical MaSAs occupied)	Historical range reduced: 75% -90% of historical MaSAs occupied	Historical range reduced: 50%-74% of historical MaSAs occupied	Historical range reduced: less than 50% of historical MaSAs occupied

Factor A.1.c. Increase or decrease in gaps or continuities between spawning areas

Given the strong homing instincts of anadromous salmonids, significant changes in the distance between spawning areas may have impacts on gene flow within and among populations. The size of gaps between spawning areas may also affect the ability of a population to recolonize extirpated areas. A general dispersal distance relationship was used as one factor in defining distinct historical populations within Interior Basin ESUs (see ICTRT 2003 for further details). Based on that curve, dispersal or straying rates between spawning areas less than 10 km apart were relatively high. We suggest a simple index based on discontinuities between MaSAs (Table 10). The gaps criteria also incorporate consideration for the loss of spawning areas (MaSAs or MiSAs) at the lower end of populations. Such losses can substantially increase the distance from adjacent populations.

Table 10. Factor A.1.c. Criteria describing risk levels associated with a change in gaps or continuities between spawning areas.

Factor/ Metrics	Pop. Group	Risk Level			
		Very Low	Low	Moderate	High
Factor: Increase or decrease gaps or continuities between spawning areas	A,B,C,D	Population included 3 or more historical MaSAs AND All historical MaSAs currently occupied	75% or more of historical MaSAs occupied, gaps between MaSAs separated by 10 km or less	Currently occupied MaSAs separated by 10 km or more AND intervening historical spawning areas (MaSA or MiSAs) not occupied. OR Loss of MiSAs at lower end of population; increased distance to adjacent population by 25 km or more.	Occupied MaSAs separated by 15 km or more AND intervening historical spawning areas (MaSA or MiSAs) not occupied

Goal B: Maintaining natural levels of variation

This goal is aimed primarily at preserving existing genetic and phenotypic variation and, where natural patterns of variation have been altered, providing the conditions to allow that variation to be expressed. This variation or diversity is important for long-term resilience and adaptability. Relatively short-term (e.g., 5- to 10-year) observations of abundance and productivity alone are unlikely to be sufficient for the identification of a population's long-term risk of extinction because of inadequate diversity. Depending on the variability in environmental factors, many traits may not be expressed during the time intervals often used for assessing abundance and productivity. The establishment of diversity criteria provides the necessary mechanism for preserving a population's genetic resources during the recovery process, thereby increasing the likelihood of establishing or maintaining sustainable populations into the foreseeable future and beyond.

"Natural patterns and levels of variation" is not intended to specify a single point estimate of a trait (genetic or other), but rather the overall configuration of variation or potential that supported viable populations—encompassing range and distribution through time as well as average values. Thus, if a population historically occupied areas in which selective pressures alternated over long time periods (e.g. decades), the range of variation that allowed it to persist in that area should be preserved. Some judgment will be required in the application of the metrics supporting this goal, since historical patterns of variation are poorly, if at all, characterized. Potential sources of comparison for these metrics include historical information; other, more robust populations with similar characteristics; and expert judgment. These metrics provide a structure within which to consider variation, and outline the key elements that should be considered in any rating.

Importantly, in a relatively stable environment, a change in phenotypic mean away from a natural optimum can be considered as deleterious. However, Interior Columbia salmonids inhabit an environment that is not only changing now, but has also changed substantially over the last hundreds and thousands of years (e.g., Mantua and Hare 1994, Chatters et al. 1995). In addition, change in mean phenotype can also be indicative of a beneficial adaptive response of a population to an environment which has been altered, and for which a new natural optimum has been established. Two additional factors are thus important to consider while assessing populations with respect to this metric. The first is that not only the mean, but also the range of phenotypes or genotypes present in a population are important. An anthropogenic activity that maintains the same mean within a population, but dramatically reduces the variance should be considered selective, as the range of phenotypic expression has been dramatically reduced. In situations where the mean has changed in an apparently adaptive manner, care should be taken to ensure that the new "optimum" allows the population to be sustainable in other life stages and locations (e.g. genetic or environmental correlation between this trait and others should not reduce fitness at other life stages), and that a natural range of expression can still be achieved.

We identified four mechanisms that support our goal of maintaining natural levels of variation. We arranged these in a hierarchy, from direct measures of phenotypic and genotypic variation to indirect measures of environmental or other conditions that likely influence that variation. We include indirect measures for these two reasons. First, in many cases, direct measures of

diversity are not available. Second, even when available, detectable change in phenotypic or genotypic measures may lag behind the impact causing that change. Including indirect, causal mechanisms thus serves to identify situations that are likely to become detectably impaired. Because the effect of these indirect measures on phenotypic and genotypic variation is in many cases less certain, we weight these indirect, causal mechanisms less heavily than direct measures.

Mechanism B.1: Maintain natural patterns of phenotypic and genotypic expression

This mechanism focuses directly on observed genotypic and phenotypic variation within populations and on changes in that variation. This is the variation that we seek to preserve in viable populations. Changes in these natural patterns are the strongest possible evidence that the population may be at risk with respect to diversity.

Factor B.1.a. Major life history strategies

Major life history patterns represent adaptations to environmental variation. We consider a major life history strategy to include a suite of phenotypic characteristics that are relatively correlated (at least phenotypically). Summer run-timing in stream-type chinook salmon, for example, rises to the level of a major life history strategy, as it encompasses not only adult run-timing, but also spawn-timing, age structure, size and to some extent, habitat preferences. Although life history strategies are a subset of phenotypic expression, we did not include this factor within "phenotypic variation" because we believe evidence indicates that these suites of characters were particularly important for overall population viability, and thus are less tolerant of loss or change in these characteristics.

Within an ESU, the dominant life history patterns may differ among populations in response to large scale patterns in environmental conditions or geographic patterns in habitat availability. Within a population, variations in life history patterns likely provide a buffer against high mortality in a particular year or habitat type (Healy, 1991). Particular combinations of adult run timing and spawning timing represent adaptations to the timing of flow and temperature conditions (Lichatowitch & Mobrand, 1995). Freshwater survival through juvenile rearing stages is an important determinant of overall productivity for stream type chinook and steelhead populations. A number of generalized movement patterns have been documented that could enhance survival through the summer and overwintering phases (ISAB, 1996; Reimers, 1973). Overwintering conditions in the relatively high elevation watersheds in the Interior Columbia can be extremely harsh. Late fall movements of a substantial proportion of age 0+ juvenile chinook and steelhead into downstream habitat areas afforded opportunities for increased survivals (Cramer et al. 2002). Loss or substantial reductions of a particular life history pattern could reduce the average productivity of a population.

We consider the following to be major life history strategies:

- Residence and anadromy

- Seasonal run-timing, including; spring- and summer- run in the Snake River spring/summer chinook ESU, winter and summer run steelhead, A and B-run steelhead

- Significant alternative juvenile migration patterns. These should include: consideration of timing of ocean migration (e.g. subyearling vs. yearling), relative distribution for summer rearing (e.g., natal tributary vs. downstream mainstem), and relative distribution for overwintering (e.g., natal tributary vs. fall downstream emigration

Our metrics for major life history patterns consider the presence and distribution of adult and juvenile life history strategies within a population (Table 11). In many cases, historical pathways will need to be inferred from habitat assessments and information from representative systems or from model based projections (e.g., EDT). In those cases key assumptions should be clearly described and justified.

Table 11. Factor B.1.a. Criteria describing risk levels associated with major life history strategies.

Factor	Pop. Group	Risk Level			
		Very Low	Low	Moderate	High
Factor: Major life history strategies Metric: Pattern (mean, range, etc.) of major life history expression within a population	A,B,C,D	No evidence of loss in variability or change in pattern	All historical pathways present, but some non-negligible change in pattern of variation	All historical pathways present, but significant (meaningful) change in pattern of variation	Permanent loss of major pathway (e.g. anadromy for *O. mykiss*, or loss of a juvenile pathway)

Factor B.1.b. Phenotypic variation

This factor includes morphological, life history, and behavioral traits. Because phenotypic traits are subject to natural and other selective events, the loss or severe truncation of specific traits reduces the resilience of a population to environmental perturbations, both in the short term (annual fluctuations, multiyear cycles) and long term (shifts in climatic conditions, etc.). We assess change in phenotypic variation by examining the mean, variation, and presence/absence of each trait (Table 12). Specific information on traits may not be available for all populations. Initial status reviews may be able to incorporate inferences based on information from similar populations within the same MPG or ESU. In addition, some case-by-case consideration may be necessary, due the range of conditions in the Interior Columbia. For instance, a population with an expanding range of spawn timing may be countering previous selective pressures that had truncated its range previously (a positive effect), or may be undergoing selection against the previous mean (a potentially negative effect). These types of considerations should be weighed in assigning a risk rating for this factor.

Table 12. Factor B.1.b. Criteria describing risk levels associated with change in phenotypic characteristics.

Factor/Metrics	Pop. Group	Risk Level			
		Very Low	Low	Moderate	High
Factor: Phenotypic variation Metric: Reduction in variability of traits, shift in mean value of trait, loss of traits.	A,B,C,D	No evidence of loss, reduced variability, or change in any trait	Evidence of change in pattern of variation in 1 trait (e.g., migration timing, age structure, size-at-age)	Loss of 1 trait or evidence of meaningful change in pattern of variation in 2 or more traits	Loss of 1 or more traits and evidence of change in pattern of variation in 2 or more traits; or change in pattern of variation of 3 or more traits (e.g., loss of a spawning peak and significant reduction in older age fish)

Factor B.1.c. Genetic variation

This factor addresses observed changes in genetic variation, regardless of the cause of that change (e.g., whether the change is due to introgression from non-local hatchery spawners or from the adverse genetic consequences of small population size).

We recommend that current and past population-specific genetic data sets be evaluated under four considerations:

- The amount of genetic variation detected within the population or subpopulations;
- The level of differentiation between subcomponents of the population
- The level of differentiation between the population and other populations (including hatchery stocks)
- Temporal change in levels of variation or differentiation within and between populations

These characteristics may be expressed by such measures as statistically significant reductions in heterozygosity, number of alleles, changes in allele frequencies, presence of non-native alleles, or as among locus (gametic) or within locus (genotypic) disequilibria consistent with ongoing or recent admixture with non-native populations.

However, we did not include specific genetic metrics or cutoffs in our criteria for three reasons. Most importantly, the wide variety of circumstances in the interior Columbia Basin requires a case-by-case examination of genetic data. For instance, available baseline genetic information may not be a reasonable picture of natural levels of genetic variation due to bottlenecks the population has experienced, or to extreme introgression from hatchery fish. Therefore, in some cases, change from a baseline might reduce the apparent risk to a population, whereas in others, the same degree of change might constitute a significant increase in risk level. Second, the ever-changing nature of molecular genetic techniques and analyses suggests that new advances may provide additional or improved methods to measure genetic variation. Finally, degree or magnitude of differentiation that could be gauged to be "high" or "low" will vary between

species and data type and quality.

We do suggest risk levels associated with degree of change from "actual or presumed historical conditions" for genetic characteristics (Table 13). Requiring populations to show low levels of change from "actual or presumed historical conditions" is not meant to imply that the population must have the precise distribution of alleles that it had historically. Rather, we mean that the general pattern of differentiation exhibited within and between populations should be similar to that which existed historically (if a suitable baseline exists) or that which can be inferred as being likely from similar populations where reliable genetic inferences have been made.

Two issues relevant to categorizing a population with respect to this genetic criterion are worth particular mention. The first is the relatively slow response of neutral genetic markers to genetic drift. Populations that have been homogenized with each other, or with a hatchery stock, will not, if they maintain relatively large population sizes, show levels of differentiation consistent with those that existed historically in short time scales. In these situations, certain analyses can be used to assess whether the population merits a risk rating lower than is immediately apparent from its genetic characteristics:

− a fine-scale genetic analysis indicating that substructure within the population exists (i.e. that fish spawning in geographic proximity also show greater genetic affinity than they do to fish spawning more distantly). This structure should be confirmed across the population, and not be confined to a small portion. In addition, a sufficient number of generations to ensure high confidence in the results should be included;

− an analysis of genetic data indicating that the amount of divergence seen, even if differences between populations are not significant, is consistent with the time since the cessation of the perturbation and a very low level of exchange between populations. This analysis must include several samples both within and among the populations of interest;

− a robust analysis of patterns of dispersal. This would include sufficient spatial and temporal coverage to have high confidence that the population is neither receiving nor distributing out-of-population spawners at a rate that is above the expected frequency in natural situations, and that within population spawners are distributed in a manner consistent with natural situations. An analysis of this type is inferential with respect to our genetic criterion, and should thus be invoked with caution.

These analyses would be relevant for evaluating the characteristics of populations in the following management scenarios: re-introductions, re-building after population bottlenecks, and re-establishment of natural populations after an unnatural homogenizing event, such as overwhelming the population with hatchery-origin spawners.

Table 13. Factor B.1.c. Criteria describing risk levels associated with change in patterns of genetic variation.

Factor	Pop. Group	Risk Level			
		Very Low	Low	Moderate	High
Factor: Genetic variation Metric: Genetic analysis encompassing within and between population variation	A	No change from likely historical conditions	No change from likely historical conditions or evidence for a consistent trend towards historical conditions	Low level of change from likely historical conditions or evidence for a consistent trend towards historical conditions	Moderate or greater level of change from likely historical conditions
	B	No change from likely historical conditions	Low level of change from likely historical conditions or evidence for a consistent trend towards historical conditions	Moderate level of change from likely historical conditions or evidence for a trend towards historical conditions	Significant change from likely historical conditions
	C,D	No change from likely historical conditions	Criteria for A or B populations, dependent upon number of MaSAs in population	Criteria for A or B populations, dependent upon number of MaSAs in population	Criteria for A or B populations, dependent upon number of MaSAs in population

Mechanism B.2: Maintain natural patterns of gene flow

Maintaining natural patterns of gene flow is an indirect means of maintaining natural patterns of variation. We included spawner composition as an important factor supporting this mechanism. However, gaps within the population, and restrictions of spatial range (Factors A.1.b and A.1.c.) can also affect within and between population gene flow.

Factor B.2.a. Spawner composition

Natural breeding groups of Pacific salmon and trout (*Oncorhynchus* spp.) tend towards maintenance at natal localities because of strong homing capabilities coupled with localized adaptations (Hendry et al. 1998, 1999, NRC 1996, Reisenbichler et al. 2003). Stability of such aggregates over generations through centuries, and as fine as the local reach (Gharrett and Smoker 1993, Bentzen et al. 2001), is influenced by numbers of returning natal individuals (Waples 2004), ecological variability (Montgomery and Bolton 2003), and gene flow from exogenous fish (Utter 2001). This spatial and potentially adaptive level of variability within and between populations is recognized as important and necessary for viability of salmonid populations (McElhany et al. 2000).

The stability of salmonid population structure can be undermined by effective straying resulting from returning hatchery releases and natural-origin strays induced by anthropogenically altered conditions. Such increases of gene flow above natural levels are counterproductive to recovery efforts within listed ESUs because of hatchery adaptations or domestication (Epifanio et al. 2003, Waples and Drake 2004), losses of genetic variability through supportive breeding (Ryman and Laikre 1991, Wang and Ryman 2001), and erosions of natural population structure such as homogenization (Utter 2005). The ultimate impact of these increases in gene flow is dependent upon the duration of the increase, the proportion of exogenous spawners, and the origin of those

spawners.

For this metric, we consider exogenous spawners to be all fish of hatchery-origin AND all natural-origin fish that are present due to unnatural, anthropogenically-induced conditions, but would not normally be present within the population. Upriver steelhead straying into the Deschutes River as an apparent result of unnatural high temperatures in the John Day reservoir would be one candidate for this category.

We have developed a flow-chart approach to assigning risk associated with exogenous spawners in salmonid populations (Figure 9). Our approach is sequential, and evaluators should consider exogenous spawners in their population in the sequence laid out. Our approach considers the source of the exogenous spawners first, providing increasing tolerance for both proportion and duration of exogenous spawners the more closely related they are to the population of interest. For exogenous spawners derived from the local population, we then consider the type of hatchery program from which those spawners were derived, allowing greater input from hatcheries using "best management practices." Rather we suggest that hatchery programs that conform to the principles described in recent publications (e.g. Flagg et al. 2004, Olson et al. 2004, Mobrand et al. 2005) could be considered to have "best management practices." These will change over time as our understanding of the impact of hatchery management practices on genetic, phenotypic and fitness characteristics increases. Main components of the program to be considered include brood stock selection, efforts to minimize within-population homogenization, actions to prevent domestication or other in-hatchery selection, breeding protocols, rearing and release protocols and other efforts to minimize effects on population structure and fitness components. Future assessments should consider advancements and updates in hatchery science when determining which category a particular program should be ascribed to.

These criteria are generally consistent with other efforts to quantify risk from hatchery origin spawners (Mobrand et al. 2005). However, we do encourage case-by-case treatment of conditions that may affect the risk experienced by the population. For instance, if exogenous spawners are localized within a large, complex population, leaving the bulk of the population unaffected, a somewhat higher proportion and/or duration of those exogenous spawners could be associated with a lower risk level. Similarly, in a very diverse MPG, the presence of exogenous spawners derived from a highly divergent population (even within that same MPG) might merit higher risk levels than shown. While we offer this flexibility, such situations should be well-documented and justified.

There are several more detailed considerations for applying our criteria. First, when assessing the current status of a population, conditions in the most recent three generations should be considered. Second, the proportion of spawners belonging to a category should be calculated using the total number of spawners in the denominator. Third, if there are multiple sources of exogenous spawners within a single population, the total proportion of exogenous spawners should be considered. In general, the highest risk level assigned to any of those sources should be used for this metric, unless there are two or more "moderate" rated sources, in which case a risk level of "high" should be used. However, there may be situations where spawners from each source would yield individually a low rating, but the total proportion of exogenous spawners is relatively high. In these cases, the risk rating should be increased appropriately to either

moderate or high. Fourth, there may be cases where population specific estimates of the hatchery origin proportion of spawners are not available but circumstances indicate relatively high hatchery contribution rates are likely (e.g., nearby major release site, evidence for straying into other nearby natural areas). The risk rating applied in those cases should reflect the potential contribution levels of hatchery spawners. Finally, we do not extend our criteria beyond 5 generations for any source of exogenous spawners, because there is considerable uncertainty about the long-term impacts of this unnatural gene flow. We anticipate that future research will allow these criteria to consider longer time periods more robustly.

This metric offers the opportunity to contribute to planning efforts as well as to evaluate current risk. Conservation and/or supplementation programs may be desirable to mitigate short-term extinction risk, for example. In these cases, this metric provides a transparent means to plan and coordinate recovery efforts to minimize the risks from such a program.

Mechanism B.3: Maintain occupancy in a natural variety of available habitat types

Maintaining spawner occupancy in a natural variety of available habitat types is another mechanism to maintain natural patterns of variation. Differing habitats allow or promote the expression of differing phenotypes (Hendry and Quinn 1997, Hendry et al. 1998, Waples et al. 2001). Conceptually, the greater the range of habitat types available, the greater the potential for a population to express phenotypic diversity.
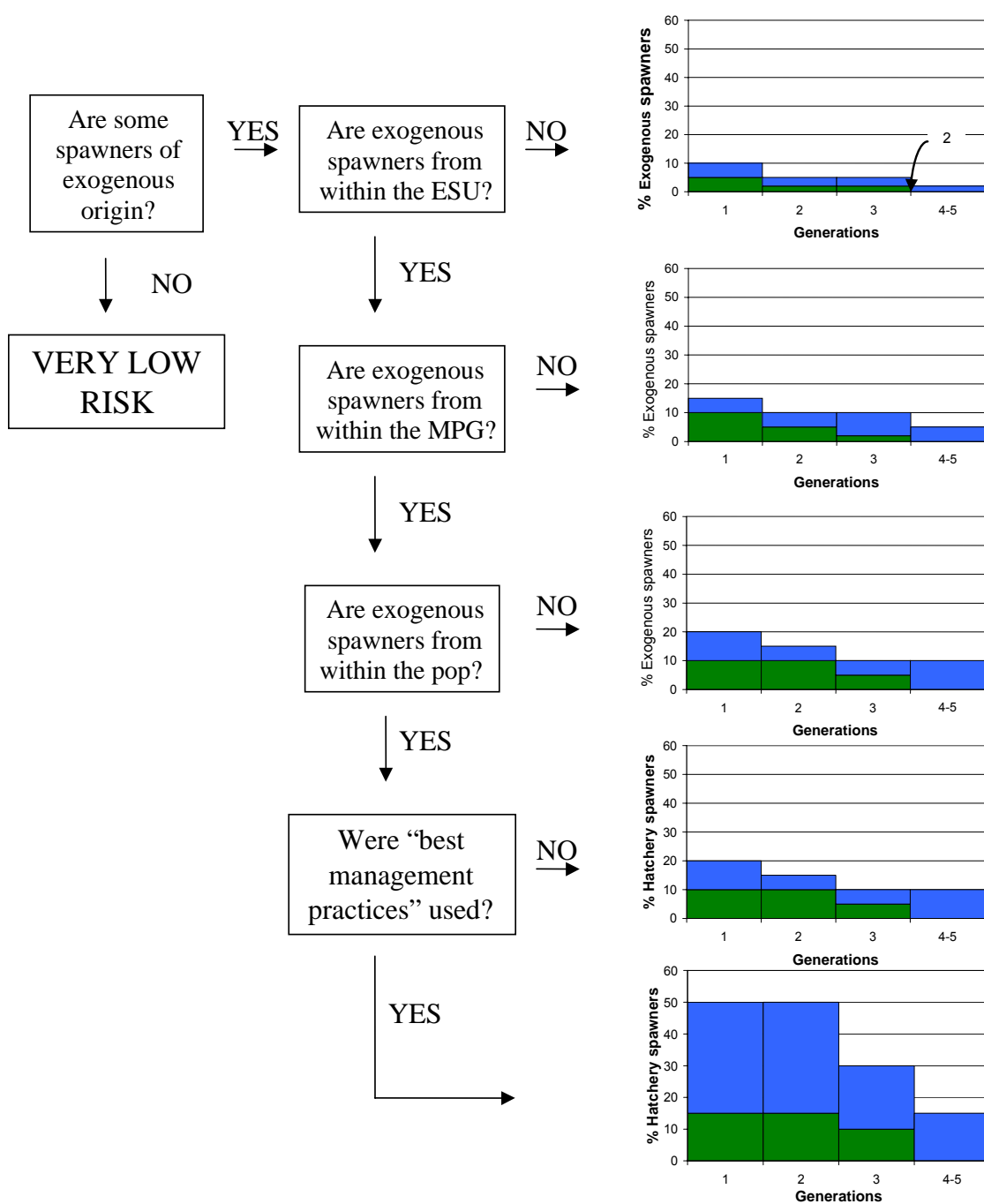
Figure 9. Risk criteria associated with spawner composition for viability assessment of exogenous spawners on maintaining natural patterns of gene flow. Green (darkest) areas indicate low risk combinations of duration and proportion of spawners, blue (intermediate areas indicate moderate risk areas and white areas and areas outside the graphed range indicate high risk. Exogenous fish are considered to be all fish hatchery origin, and non-normative strays of natural origin (see text).

Factor B.3.a. Distribution of population across habitat types

Salmonids regularly show local adaptations to habitat conditions they experience (Crossin et al. 2004). We rely on evidence that unique aquatic habitat types are produced within the context of the terrestrial ecosystems that encompass or border stream segments (e.g. Frissell et al. 1986). This relationship between a terrestrial ecosystem and its incorporated aquatic system is apt to be strongest for small streams and rivers and to be weaker for large rivers. We consider the range of habitat types occupied by a population as part of our spatial structure/diversity scoring system. A habitat diversity metric is intended to identify situations where that range of occupied habitats has changed substantively from its historic condition.

We use EPA's ecoregion classification (Level IV) (Omernik 1987, Gallant et al. 1989, Omernik 1995) to assess the historic (intrinsic) and current range of habitat types occupied. This was done by determining the distribution of intrinsic spawning habitat for a target population among the terrestrial ecosystems described by Omernik (1995). EPA Level IV ecoregion classification has the advantage of being widely accessible, well-documented and providing continuous coverage throughout the Columbia basin. These ecoregions were not developed with a focus on aquatic habitat, and their development variably includes attributes such as precipitation, land form, geology, and vegetation that influence aquatic habitat diversity. However, they are strongly correlated with differences in elevation, precipitation, and temperature regimes (ICTRT, unpublished data). Thus, as a first approximation, we believe that they capture reasonably some of the relatively substantive differences in habitat and environmental conditions that we are seeking to identify. We do note, however, that future work aimed at characterizing habitat diversity associated with population-level phenotypic and genetic diversity would be extremely useful for refining this metric. Among the likely tools for classification of habitat characteristics of biological relevance, we note some useful hydrological analyses, such as those developed by (Orsborn 1990, Lipscomb 1998).

Our approach to defining the relative risk associated with major shifts in distribution of spawners relative to ecoregions is illustrated in Figure 10. We define substantial changes in occupancy relative to historical distributions based on our intrinsic potential assessment. Ecoregions that supported more than 10% of the historical spawning area within a population are considered in the analysis. We defined a substantial change in relative distribution as a reduction of 67 percentage points or more in the relative distribution of spawning within an ecoregions that historically contained more than 10% of the weighted spawning area for a population. For example, if ecoregions X contained 50% of the total historical spawning area for a population, and that ecoregion currently represents 15% of the spawning area, the relative distribution has shifted by (50 - 15)/50 or 70%. In this case the shift would be counted as a substantial change.
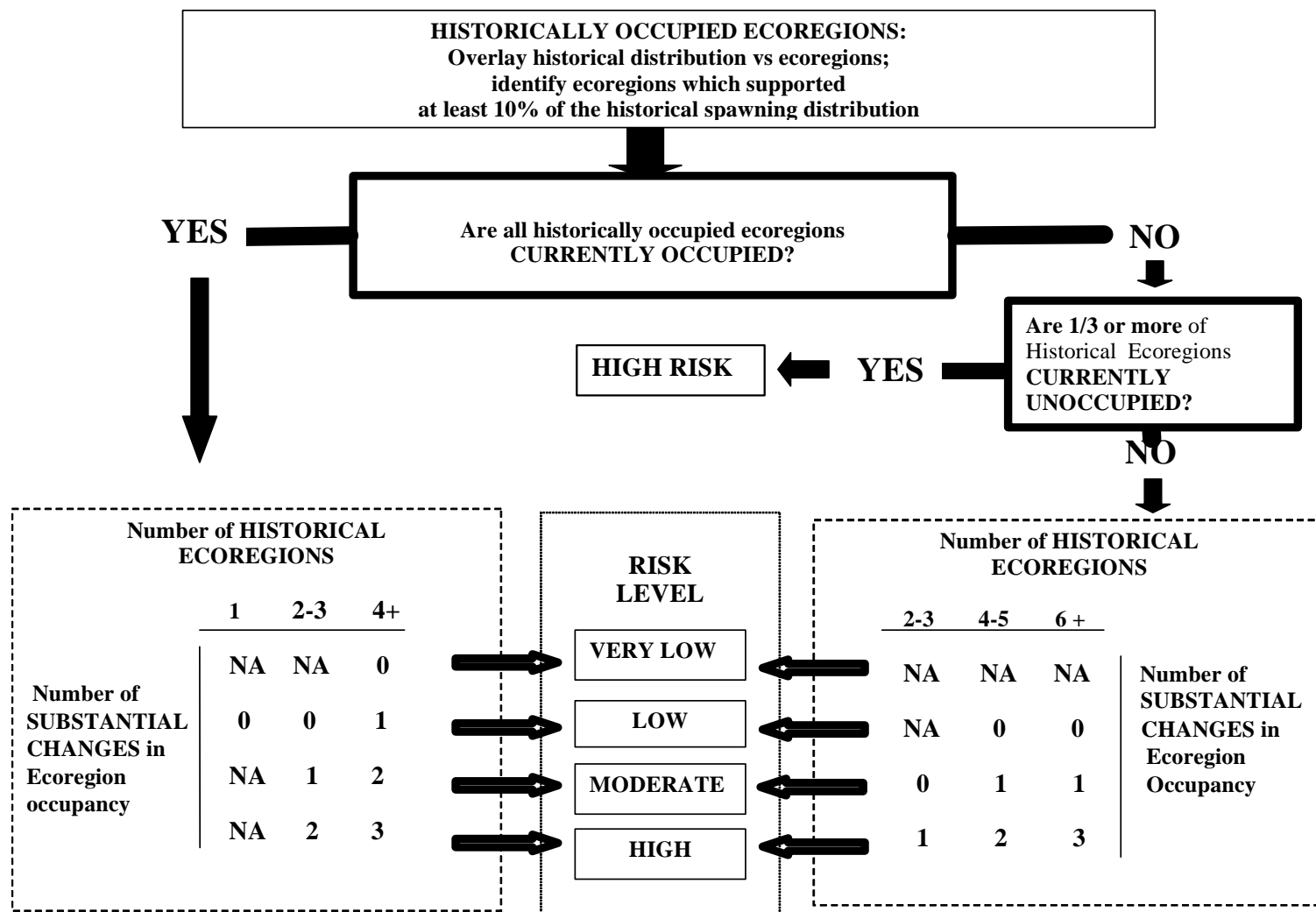
HISTORICALLY OCCUPIED ECOREGIONS:
Overlay historical distribution vs ecoregions;
identify ecoregions which supported
at least 10% of the historical spawning distribution

YES

Are all historically occupied ecoregions
CURRENTLY OCCUPIED?

NO

Are 1/3 or more of
Historical Ecoregions
**CURRENTLY
UNOCCUPIED?**

HIGH RISK ← **YES**

NO

Number of HISTORICAL
ECOREGIONS

	1	2-3	4+
Number of SUBSTANTIAL CHANGES in Ecoregion occupancy	NA	NA	0
	0	0	1
	NA	1	2
	NA	2	3

RISK LEVEL

VERY LOW

LOW

MODERATE

HIGH

Number of HISTORICAL
ECOREGIONS

2-3	4-5	6 +	
NA	NA	NA	**Number of SUBSTANTIAL CHANGES in Ecoregion Occupancy**
NA	0	0	
0	1	1	
1	2	3	

Figure 10. Evaluating changes in spawner distribution versus ecoregions.

Mechanism B.4. Maintain integrity of natural systems (Avoid selectivity in anthropogenic activities)

Maintaining the normative functioning of natural systems across the population's life cycle is an important component of maintaining natural patterns of diversity or variation. Disruption to the systems inhabited by natural salmonid populations can engender selective responses of these populations. For example, size-selective harvest has likely shifted size and/or life history traits (Handford et al. 1977, Ricker 1981, Healey 1986, Hamon et al. 2000, Hard 2004). Similarly, alterations to habitat conditions affecting the hydrograph, could substantially alter juvenile outmigration or spawn timing (Beechie et al., in press). Hatchery broodstock collection that preferentially removes one temporal component of a run could also have a selective impact on the natural population (McClean et al., Tipping and Busack 2004, 2003). Importantly, in identifying each of these activities it is not only that change in the system has occurred, but also that the change has a selective effect. In other words, that change causes a shift, truncation, or other alteration to the normal variation, and thus the fitness of the population, rather than merely a decrease in overall population survival or abundance, which is addressed in the abundance and productivity criteria. The selection may occur directly, through selective mortality or removal of individuals with a particular phenotype, or more indirectly, by reducing the fecundity or mating success of individuals with certain characteristics. Critically, the focus of this mechanism is on <u>activities</u> that affect normal variation rather than change in that variation itself (which is addressed in genotypic and phenotypic measures). The inclusion of this metric allows risks to diversity to be identified even in cases where phenotypic information is lacking.

Factor B.4.a. Change in natural processes or impacts

This metric aims to identify those activities that have the potential to cause substantial anthropogenic change in phenotypes in a relatively short time frame (e.g. 100 years). The magnitude of response to any selective force is determined by the heritability of a trait and the strength or intensity of selection (Lush 1937, Falconer 1960, Lynch and Walsh 1998). The "shape" or quality of that response is affected by the type of selection. In general, a force that selects for an optimum value will cause an exponential change in the value, ultimately reaching an asymptote, whereas a constant, directional force that selects against, for example, individuals at the largest end of the distribution, regardless of actual value will produce a more or less linear response (Figure 11). Of note, this linearity of response will only last as long as there remains sufficient genetic variation in the population to maintain a constant heritability. Eventually, persistent selection will deplete this variability, heritability will decrease in response, and the change in trait value will become asymptotic at a some physiologically limited maximum or minimum value (Hallerman 2003). Greater selection intensity will produce a greater response than a low intensity of selection (Figure 12). And, higher heritability will produce a more rapid and greater response (Figure 13) than will occur in a trait with a lower heritability.
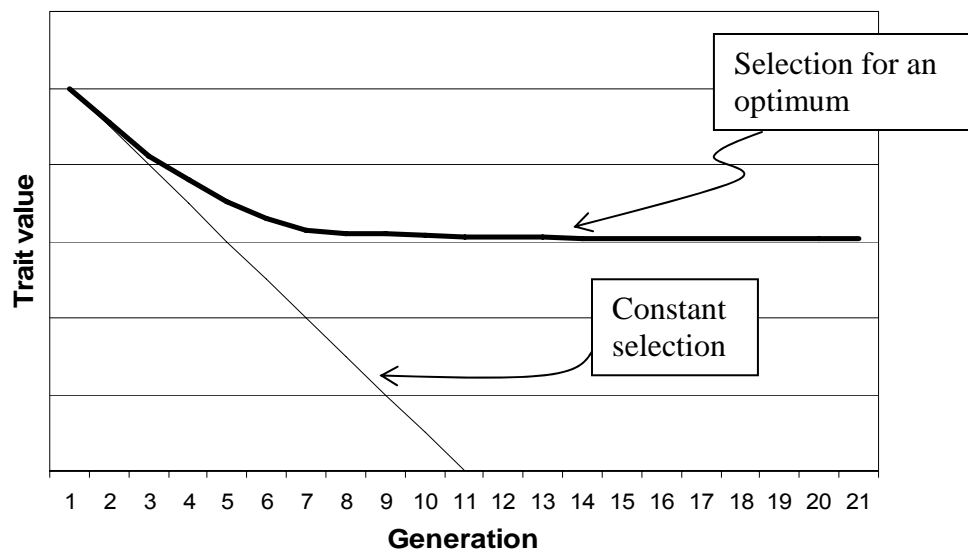
Figure 11. Constant, directional selection vs. selection for an optimum, given the same initial strength of selection and heritability. The y-axis in this graph is directionless, and is not intended to indicate that all selection will be against individuals with larger trait values. Asymptotic
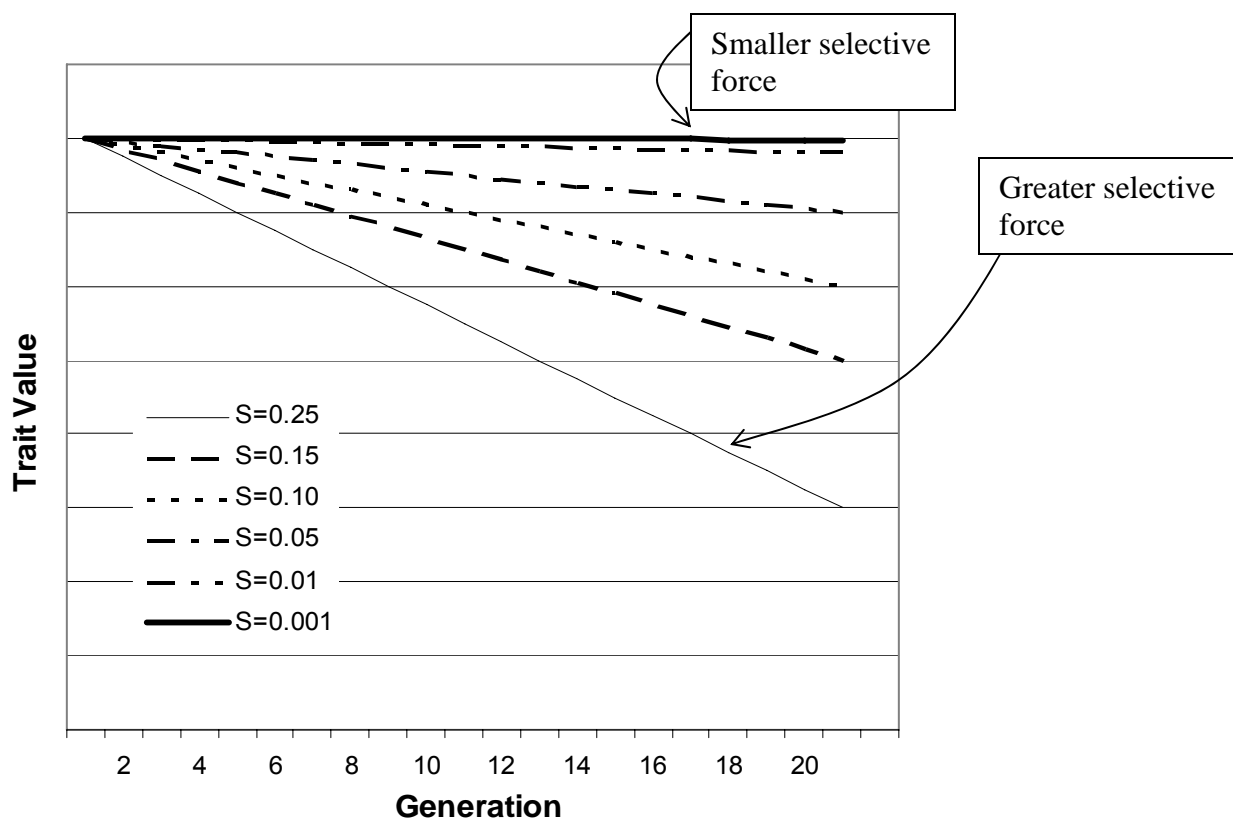

Figure 12. Trait response under varying strength or intensity of selection, with a constant heritability. The y-axis in this graph is directionless, and is not intended to indicate that all selection will be against individuals with larger trait values.
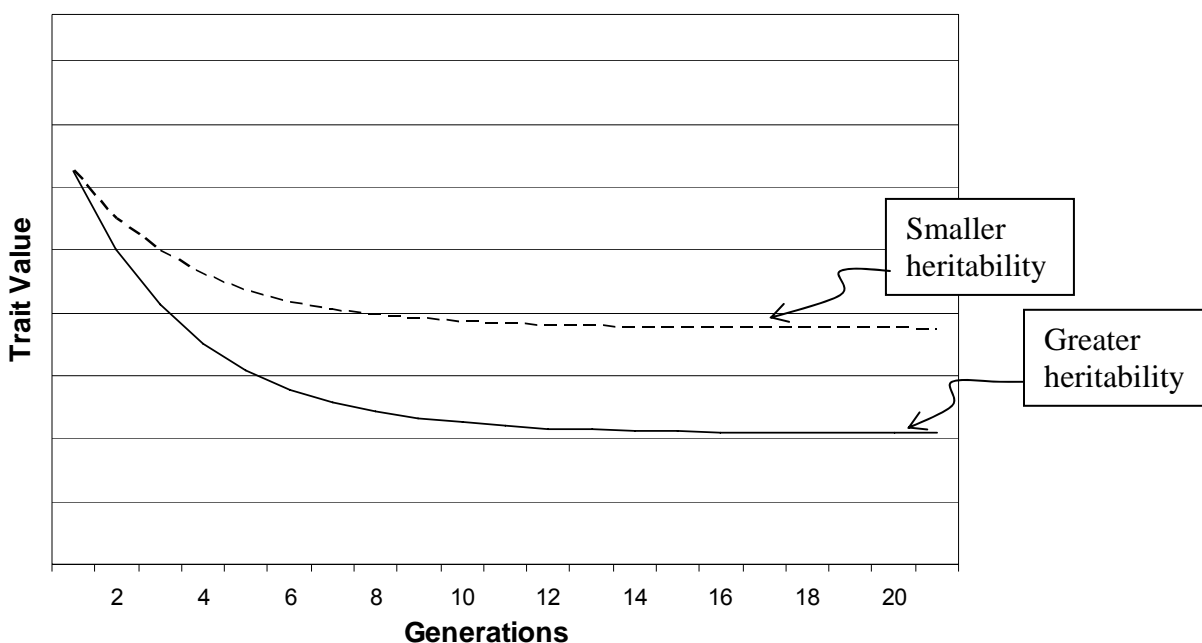
Figure 13. Differential response to selection for an optimum, under different heritabilities and the same selection
intensity. The y-axis in this graph is directionless – the graph was drawn to show a decrease in the trait
value; for other traits a decrease could be deleterious.

Assigning Risk Associated with Selective Activities

To assign risk associated with selective activities definitively, we would need to know the effect
on mean fitness that the population change in phenotype (or in the range of phenotypes
expressed) produced. Assessing these fitness effects, however, is very difficult, particularly for
fitness traits in wild populations. Moreover, the phenotypes of poikilothermic animals, such as
fish, appear to be more strongly developed in response to environmental influences, than
homeothermic animals. In consequence, measures of heritability and of strength of selection for
natural fish populations, are fairly limited in number and of poor precision (Hallerman 2003). In
the absence of reliable quantified measures, we calculated the values of two phenotypic traits
when reduced by standard proportions (Table 14) in order to assess qualitatively the potential
ecological and demographic consequences of such a change. Given this information, we suggest
that combinations of heritability and selection intensity that produce a 5-10% change in the mean
should be regarded as moderate risk; combinations of heritability and selection intensity
producing a change in the mean greater than 10% should be regarded as high risk. These
suggested boundaries can be modified if additional information about these or other traits
indicates that it would be appropriate.

Table 14. Proportional reductions in mean age at return (SRSS chinook) and length (SR fall chinook). This information was used to inform the suggested magnitude of change that would be associated with risk levels.

% Reduction	Mean Age at Return	Mean Length
0	4.2	85.0
1	4.2	84.2
2	4.1	83.3
5	4.0	80.8
10	3.8	76.5
20	3.4	68.0
25	3.2	63.8
50	2.1	42.5

In Figure 14 we present a decision process for assigning risk associated with selective activities. This framework considers the duration of the activity, the intensity of selection, and the heritability of the trait as factors that influence the magnitude of likely phenotypic response (Falconer 1960). Recognizing that empirical data describing the selection intensity on or heritability of a trait is very limited; we provide a qualitative illustration applying the metric in Box 1, and some general discussion below to assist with rating these factors.

Duration of the activity -- A selective activity that continues for less than a generation is much less likely to have a long-term effect on the population than one that has persisted for several generations. Those activities that have occurred for one generation or less can be regarded as very low risk. Intermittent activities (e.g. those felt in two out of every five years), which do not affect an entire generation, can also be regarded as lower risk than those that are continuous; however, intermittent activities that have occurred for protracted periods will have a larger effect. Finally, those selective activities that are ongoing are of greater risk than activities that have been discontinued, and we discount risk accordingly. Activities that have not occurred within five generations and are unlikely to be re-instated can be disregarded. (Note that the effects of these activities may still be perceptible in the population, but the point of this metric is to identify activities that are posing a risk to the population's diversity currently.)

Heritability – Heritability describes the proportion of phenotypic variation that is attributable to genetic variation, versus that which is environmentally determined. In general, morphological traits of organisms will tend to have relatively high heritability, while heritability for life history traits (presumed to have more direct association with fitness) will be low (Mousseau and Roff 1987, Falconer 1989). Nonetheless, maturation timing in several salmonid species has been shown to be among the most heritable of phenotypic traits in salmonids, with heritability values (h^2) of 0.50-0.65 (e.g. Dickerson et al. 2005, Kinnison et al. 1998, Hankin et al. 1993, Heath et al. 2002, Mousseau et al. 1998). Male body size, on the other hand, has been shown to be much more plastic in at least two species (Beacham and Murray 1988, Mousseau et al. 1998), with h^2 values of less than 0.3. However, it is unclear whether heritability measured in the laboratory is a good indicator of the heritability of a trait in the field (Weigensberger and Roff 1996, Hallerman 2003). Moreover, the heritability of a trait will be reduced through time as selection occurs (review

in Hallerman 2003). Without a more complete understanding of trait heritability, there is no single cut-off value between "high" and "low" heritability categories for phenotypic traits, and a relative heritability should be considered. In general, those traits that are similar to spawning and migration timing in having some indication of a substantive genetic component can be considered to have "high" heritability; those that are substantially environmentally-driven at an individual level should be considered to have "low" heritability.

Strength of selection – Strength or intensity of selection will vary with the mean of the trait in the population before selection, the mean of the selected animals, the distribution of the trait, the proportion of the population affected and the type of selection (e.g. whether the selected animals are killed before they reproduce, vs. facing a small percent reduction in their fecundity). Actions that remove animals prior to reproduction will obviously have a greater selection intensity that those reducing fecundity slightly. Actions that change the difference between the means before and after selection will also have a higher selection intensity. Thus, situations that select against a relatively large component of the population at one end of the distribution, that select strongly against the likely natural mean, or that exert selection in a population with a relative narrow range of variation in the trait will all have higher selection intensities than the reverse situations. Actions that appear to affect relatively large components of the population or act strongly against the likely natural condition can be considered to have a "High" selection intensity. Actions affecting a very small component of the population can be considered to have a "Low" selection intensity.

Although this metric requires some application of judgment and review of previous work, we believe the value of identifying situations in which anthropogenic activities alter natural patterns of variation is high, particularly since so few populations have current or past phenotypic information available.

The TRT is reviewing the selective impacts of hydropower, harvest and hatchery activities affecting multiple populations within Interior Columbia ESUs that can be used in status assessments.

Assigning Risk in Populations Affected by Multiple Selective Activities

Some populations may be affected by more than one selective activity. Two issues are important for assigning risk in these situations. The first is identifying what component of the population has been affected. In cases where more than one activity affects the same component of a population (e.g. two activities both affect early out-migrants), those two activities should be treated jointly when working through the decision process outlined in figure 14. The second issue is devising a cumulative score for the multiple activities (or joint activities). In these cases, once all activities have been considered, each activity (or joint activities affecting the same component of the population) should be assigned a risk level using Figure 14. The population risk level is set at the highest risk level for any single factor in most cases. The single exception to this approach is the case in which three or more factors are all rated as moderate. In this case, we consider that the cumulative effect of those activities will likely be additive, and is sufficient to merit a high risk rating for the population.
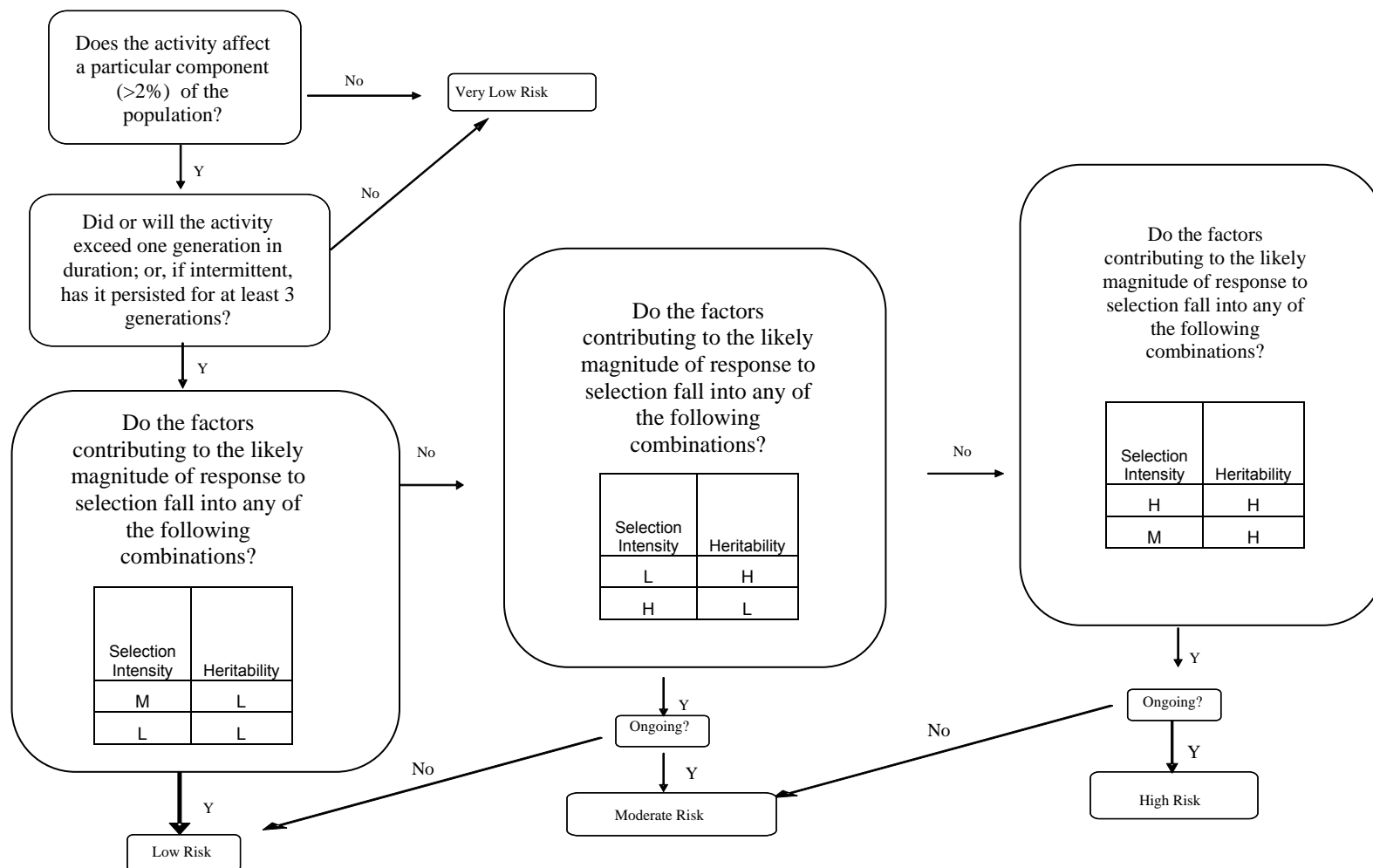
Figure 14. Decision process for assigning populations to a risk category associated with selective activities. Activities affecting the same component of the population should be considered simultaneously in this process. If multiple actions are selective in nature effect a single population that population will receive the highest risk category associated with a single action except in the case where 3 or more actions are associated with moderate risk in which case the population will be assigned to the high risk category for selective actions.

Box 1. Application of Selectivity Metric to a Hypothetical A-run steelhead population.

Scenario: In our hypothetical A-run steelhead population, 30% of the fish return as 1-ocean
fish, and 70% return as 2-ocean fish. A fishery targeting this population removes
approximately 8% of the returning 1-ocean fish, but 14% of the returning 2-ocean fish,
because they are larger. Thus, 2-ocean fish are slightly, but disproportionately
affected on two traits: their age of maturation and their length.

Change in the mean: Without the fishery, the average age of returning fish is 1.7 years:

Mean age = sum of (proportion of fish at each age*age)

Mean age = (0.3*1)+(0.7*2)=1.7

With the fishery, the mean of the fish left to reproduce is slightly different. One-ocean
fish make up 71.4 percent of the population, 2-ocean fish make up 28.6 percent and
the mean changes accordingly:

Mean age = (0.314*1)+(0.686*2)=1.686

Interpreting the change in mean: This change in mean yields a difference, or selection
differential of 0.014 (see Figure 2 for the effect of alternate selection differentials on
expected magnitude of response). If the heritability of the trait in question is high, as
is age of maturation, this metric would receive a "moderate" rating. [If the proportion
of 2-ocean fish had been lower (e.g. 30%), the total proportion of the population
affected would have been less than 5% and the rating would be very low.] The same
process could be followed for length, but the heritability would be low. These ratings
would be decreased if the action is no longer ongoing.

Generating a Final Spatial Structure and Diversity Rating

Table 15 provides the "tool" or framework to integrate these several metrics and determine a population's composite risk level associated with spatial structure and diversity (SS/D). The table is organized hierarchically with the two primary goals of the SS/D criteria (McElhany et al. 2000) in the leftmost column. For each goal, one or more mechanism to achieve that goal is given in the next column. In general, these mechanisms describe the conditions associated with natural healthy populations. The third column lists the factors associated with each mechanism. Factors in this context are individual and population-level attributes that characterize each mechanism. The metrics outlined in the fourth column are the quantitative and qualitative measures used to assess a population's risk status relative to each metric.

The next four columns are a mirror image of the first four and provide the rules under which each metric score is assimilated up the hierarchy of the risk table. Risks are entered at the metric level and then carried through to higher levels to the right. For example, at the Factor level, metric A.1.a is assigned the risk level it was given at the Metric level. For comparison, B.2.a metrics 1-3 are integrated at the factor level following the rule set provided in the table. Metric scores across the entire table are integrated in a similar manner until the final column is reached which provides the population-level risk associated with SS/D.

The rules governing the integration at each level are intended to reflect the effect each metric would have on SS/D. Factors expressed in terms of direct metrics are integrated at the mechanism level by calculating the mean of the three metrics, effectively assigning a higher weight to direct measures of SS/D criteria. At the goal level the mean of the direct metrics is used for the same reasons. In those cases where the mean ends in a decimal part of 0.5 or less, round down to the higher risk level. The lowest score (highest risk) from the three B1 metrics is carried through the table to the factor and mechanism levels. To the extent possible, B1 metrics are measured deviations from natural patterns of phenotypic or genotypic expression. Thus, any measured deviation is likely to be an indicator of undetected changes and constitutes a substantial risk at the SS/D level. These are direct measures of phenotypic or genetic change in the population, and are given the highest weight in the overall integration of the B metrics. B2 metrics describe the influence that hatchery stocking may have on natural patterns of gene flow. In general, these metrics are integrated in the same manner as B1 metrics, the highest risk is carried through to the factor and mechanism levels. However, the case in which two or more of the metrics are rated moderate provides two complementary lines of evidence that hatchery stocking is altering the natural conditions and the risk level is increased to high accordingly. Factors B3 and B4 have a single metric the score of which is carried to the factor and mechanism levels. The B-type metrics are integrated at the goal level either by taking the B1 mechanism score or by using the mean of mechanism scores B.1 – B.4, whichever yields higher risk. This approach recognizes that B1 mechanisms are direct measures of deviations from natural conditions and should be given increased attention over the remaining B metrics. The overall population risk level is determined by using either the A-goal or B-goal score, whichever is lower (highest risk).

Table 15. Scoring system for deriving a composite, population-level spatial structure and diversity risk rating. Metrics and descriptions in the "Assessed Risk" column indicate contribution of individual metrics to integrated population score (Scoring: Very Low = 2, Low = 1, Moderate = 0, High = -1).

Goal: Mechanism	Factor	Metrics	Assessed Risk			
			Factor	Mechanism	Goal	Population
Goal A: 1. Maintain natural distribution of spawning areas.	*a. number and spatial arrangement of spawning areas.*	Number of MaSAs, distribution of MaSAs, and quantity of habitat outside MaSAs.	A.1.a	Mean of A.1.a., A.1.b, A.1.c.	Mean of A.1.a., A.1.b, A.1.c.	Lowest score (highest risk)
	b. Spatial extent or range of population	Proportion of historical range occupied and presence/absence of spawners in MaSAs	A.1.b			
	c. Increase or decrease gaps or continuities between spawning areas.	Change in occupancy of MaSAs that affects connectivity within the population.	A.1.c			
Goal B: 1. Maintain natural patterns of phenotypic and genotypic expression.	*a. Major life history strategies.*	Distribution of major life history expression within a population	B.1.a	Lowest score (highest risk)	B1 Mech. Score or Mean of B.1, B.2,B.3, and B.4, whichever is lower (higher risk)	
	b. Phenotypic variation.	Reduction in variability of traits, shift in mean value of trait, loss of traits.	B.1.b			
	c. Genetic variation.	Analysis addressing within and between population genetic variation.	B.1.c			
Goal B: 2. Maintain natural patterns of gene flow.	*a. Spawner composition.*	Proportion of natural spawners that are out-of-ESU spawners.	If two metrics rated as moderate, then high risk; otherwise lowest score (highest risk)	If two metrics rated as moderate, then high risk; otherwise lowest score (highest risk)		
		Proportion of natural spawners that are out-of-MPG spawners.				
		Proportion of hatchery origin natural spawners derived from a within MPG brood stock program, or within population (not best practices) program.				
		Proportion of hatchery origin natural spawners derived from a local (within population) brood stock program using best practices.				
Goal B: 3. Maintain occupancy in a natural variety of available habitat types.	*a. Distribution of population across habitat types.*	Change in occupancy across ecoregion types	B.3.a	B.3.a		
Goal B: 4.Maintain integrity of natural systems.	*a. Selective change in natural processes or impacts.*	Ongoing anthropogenic activities inducing selective mortality or habitat change within or out of population boundary	B.4.a	B.4.a		

Generating a Final Population-level Risk Rating

The primary purpose of our population level criteria is to identify populations performing at viable or highly viable levels. Our MPG level criteria require that a minimum number of the historical populations within a particular MPG be rated as viable or highly viable. In addition, the MPG criteria require that the other populations in a MPG be maintained at levels sufficient to provide for ecological functions and to preserve options for ESU recovery.

We integrate all four VSP parameters using a simple matrix approach as a framework (Figure 15). We base our ratings of the overall status of each population two composite metrics. The A/P metric combines the abundance and productivity VSP criteria (McElhany et al. 2001) using a viability curve. The second composite metric (SS/D) integrates across twelve measures of spatial structure and diversity. Determining if the remaining populations in an MPG are satisfying the maintained criteria requires additional considerations described below.

Viable and Highly viable populations are rated directly as specific combinations of A/P and SS/D risk ratings (illustrated in Figure 15). The composite A/P and SS/D metrics are expressed relative to a 5% risk of extinction within 100 years. Populations with a Very Low rating for A/P and at least a Low rating for SS/D are considered to be "Highly Viable." Populations rated at Moderate or High risk for A/P or High risk for SS/D have a risk of extinction greater than 5% and are not considered Viable. Although SS/D status is more difficult to quantify, populations rated at high risk against our composite SS/D criteria are not consistent with long-term persistence and viability.

		Spatial Structure/Diversity Risk			
		Very Low	**Low**	**Moderate**	**High**
Abundance/ Productivity Risk	**Very Low** (<1%)	HV	HV	V	M*
	Low (1-5%)	V	V	V	M*
	Moderate (6 – 25%)	M*	M*	M*	
	High (>25%)				

Figure 15. Matrix of possible Abundance/Productivity and Spatial Structure/Diversity scores for application at the population level. Percentages for abundance and productivity (A/P) scores represent the probability of extinction over a 100-year time period. Cells that contain a "V" are considered Viable combinations. "HV" indicates Highly Viable combinations. Shaded cells do not meet criteria for Viable status—darkest cells are at greatest risk. Cells designed as "M*" are candidates for maintained status.

The ICTRT criteria require a minimum number of populations within an MPG at or above viable status, with additional MPG populations maintained at sufficient levels to provide for ecological functions and to preserve options for ESU recovery. Maintained populations contribute to the ecological functioning of an ESU in several ways. The productivity of habitats and populations is dynamic and changes over time (Reeves et al. 1995). As a result, over a number of years

source populations with higher productivities may exchange roles with sink populations with lower productivities in response to those changes (McElhany et al. 2000). The cumulative productivity across populations within an MPG should not fall below replacement (i.e. maintained populations should not serve as significant population sinks) (McElhany et al. 2000, Holmes and Semmens, 2004, Gunderson et al. 2001). In addition, if a catastrophe impacts one or more of the functioning viable populations within the MPG, the other populations will need to be at sufficient levels so that they can replenish those populations lost to or affected by the catastrophe. Maintained populations can also serve as genetic or demographic "stepping stones" between populations allowing natural patterns of gene flow and dispersal.

Maintained populations can also serve as buffers against uncertainty in the ICTRT population and MPG criteria. Ensuring that the less than viable populations meet maintained standards reduces the risk for the MPG. For example, an MPG with ½ the populations at viability and the remainder meeting maintained standards is at lower risk than an MPG with one or more populations at high risk. Additionally, having populations meet maintained standards should preserve recovery options in the event that efforts to recover other populations to viable levels fail.

Populations with specific combinations of A/P and SS/D ratings are candidates for Maintained status (Figure 15). However, it is difficult to capture all of the necessary attributes to meet the objectives for maintained populations in a simple set of integrated A/P and SS/D risk ratings. In general, populations with moderate abundance and productivity risk levels near 25% with high year-to-year variability or populations with high risk for multiple SS/D factors are less likely to be considered Maintained. A primary consideration in setting an abundance objective population in the smallest size category (Basic) would be uncertainty in current estimates of abundance and productivity. Given the levels of uncertainty in estimating recent geomean abundance and productivity, the abundance objectives for Basic populations should exceed 250 spawners to be designated as Maintained status. Populations classified in any of the three largest size categories should be at abundance levels not less than 500, and will likely require average abundance levels approaching minimum threshold values to address demographic and genetic considerations.

For each MPG, candidate populations should be reviewed individually and in context with the other populations against the above principles. Our use of a maintained population category is intended to result in similar contributions to persistence at the MPG level as would be achieved by meeting the Lower Columbia Willamette TRT requirements for a minimum average persistence score across populations within an MPG, and the Puget Sound TRT recommendation for "sustained" populations (PSTRT, 2002).

Monitoring and Evaluation

To provide general guidance for monitoring and evaluation, we identified improvements for current data collection and techniques to assess population status relative to the viability criteria. This section describes major data deficiencies but does not describe the specific sampling approaches needed to improve data quality. We highlighted major data deficiencies at the ESU/MPG level, however there are likely other population specific data needs that may be critical to viability assessment that we have not identified. In general, there were fairly large gaps in information for steelhead populations and the quality of information was generally poorer than for Chinook populations. We did not identify other M & E needs for limiting factors and action effectiveness, in this report. Key information gaps for conducting population level viability assessments include:

Abundance/Productivity:

1. Snake River steelhead population specific abundance and productivity data:
   A majority of populations had little or no recruit/spawner information to assess abundance and productivity criteria; most status assessments relied on a Snake River aggregate (Lower Granite) data set. Population level assessments for steelhead can be difficult given environmental conditions at the time of spawning, the potential distribution across stream drainages, etc. Alternative techniques should be considered (e.g., redd based surveys, weir counts combined with juvenile surveys, etc), incorporating probabilistic sampling protocols for estimating abundance.

2. Snake River steelhead population specific hatchery fraction and age structure data: A majority of populations had inadequate or no hatchery fraction information to assess abundance and productivity criteria. In addition, there is inadequate data to estimate the number of hatchery spawners in the aggregate recruit/spawner analysis. A majority of populations had no or inadequate age structure information to assess abundance and productivity criteria; most status assessments relied on a Snake River aggregate (Lower Granite) data set.

3. Upper and Mid Columbia Steelhead population abundance and productivity data: Most population abundance estimates are derived from standard index redd count surveys. Upper Columbia and Yakima population abundance are estimated from aggregate dam counts and population specific levels are apportioned using limited radio tag data. Abundance estimates need to be conducted using probabilistic sampling protocol for either redd counts or tagging studies.

4. Upper and Mid Columbia steelhead population specific hatchery fraction and age structure data: A majority of populations had inadequate hatchery fraction information. We used MPG aggregate hatchery fraction for most populations. Abundance and productivity assessments would improve with more detailed population level hatchery fraction data. A majority of populations had inadequate age structure information. Typically, average MPG aggregate age structure from a few years of data was used in most cases for the population level.

5. SARs and juvenile productivity estimates for all Chinook ESUs and steelhead DPSs: Improve or collect information on SARs and juvenile productivity (i.e. smolts per spawner). SARs are essential for taking into account variability in survival during smolt outmigration and marine life stages in evaluating A&P criteria. The goal is to estimate SARs that are representative at the population level. There are a number of approaches to accomplish estimating these SARs (e.g. marking wild or hatchery smolts or estimating natural origin smolts and adult production). In addition, measures representing survival from spawning to outmigrating smolts would aid in partitioning productivity between freshwater and marine life-stages.

6. Population level effects of hatchery spawners on natural productivity for all ESUs and DPSs: For populations with hatchery spawners, develop representative estimates of the effects of hatchery spawners on population level productivity. Topics of interest include the effect of hatchery spawner contributions to the average natural productivity of a population and the relative effectiveness of hatchery spawners. In combination with adequate estimates of the relative levels of hatchery fish contributing to natural spawning for a particular population, this information would allow for more representative estimates of current and potential natural productivity levels..

Spatial Structure and Diversity

1. Steelhead populations spawner distribution and habitat preference data: Many of populations had inadequate spawner distribution information to assess spatial structure and diversity criteria. In addition, estimates of historical distribution are dependent upon habitat preferences derived from available empirical studies. Those studies are limited in scope and number. Additional information on habitat/steelhead preference or production relationships could improve the assessment of steelhead populations against SS/D criteria.

2. Phenotypic characteristics for populations in all ESUs/DPSs: Little information was available to assess phenotypic changes. Representative estimates of current morphological, life history or behavioral traits are not available for many populations. Additional analysis of relationships between habitat characteristics and phenotypic traits would improve the ability to assess changes from historical patterns at the population level.

3. Steelhead genetics information, particularly for Upper Columbia and Mid Columbia populations: Genetic baseline information and periodic follow-up surveys specifically designed to evaluate the level of variation or differentiation among subcomponents within populations and among populations. Periodic follow-ups would support evaluation of responses to management actions designed to promote restoration of natural patterns of population structure.

4. Snake River Fall Chinook genetics sampling information allowing evaluation of population substructure: Establishing a baseline coupled with periodic future follow-up

efforts would generate information for evaluating the impacts of management strategies on population substructure.

5. <u>Spawner composition for steelhead populations with hatchery spawners</u>: Collect specific spawner composition information including proportion and source of hatchery spawners. Information on the relative distribution of hatchery spawners among production areas within populations would also improve the ability to assess status against ICTRT spatial structure criteria.

6. <u>Selective mortality effects for populations in all ESUs/DPSs</u>: Little information was available to assess selective mortality resulting from differential impacts of human induced mortality. Additional information is needed to better assess human induced mortality effects in each of the four Hs (habitat, hatcheries, harvest and hydropower)

There is considerable variability in the quality and quantity of information to conduct viability assessments for Interior Columbia River salmon and steelhead populations. We have identified fairly large gaps in information for steelhead populations and the quality of information was generally poorer than for Chinook populations. We believe improving the quality and quantity of data for the metrics and populations we identified above is essential for monitoring future change in population status relative to viability criteria.

Conclusions: Applying the ICTRT Viability Criteria

Our viability criteria reflect the hierarchical structure of Interior Columbia ESUs. ESU viability is a product of the viability of major population groups (MPG) and, in turn, the populations within them. Ecological and genetic patterns inherent in the distribution of populations within these levels contribute to the evolutionary history of the species. The viability of an ESU cannot be evaluated without first understanding the viability of these component building blocks. Thus our primary goal under this hierarchy has been to describe <u>ESU</u> viability through assessment of <u>population</u> extinction risks which consider abundance, productivity, spatial structure and diversity. Abundance plays an important role in our viability criteria, since abundance is a key element of extinction risk. However, it is important to recognize that a measure of average abundance alone is not sufficient for viability. The population and ESU level trends, distribution patterns and evolutionary potential (diversity) all contribute to ESU evolutionary and ecological functionality. Our criteria at all levels seek to tie viability to the primary drivers of evolutionary and ecological functionality.

Previous drafts of the ICTRT viability criteria were made available to provide guidance to regional recovery planning efforts that were ongoing concurrently with the development of these viability criteria. Early versions of the criteria were tested on some populations and refined based on lessons learned from the tests and input from regional recovery planners. The specific set of objectives and the particular measures associated with each component of our criteria have not changed. In some cases, the definition of certain risk levels in terms of a particular metric have been modified to facilitate more objective and consistent application of the criteria as well

as to reflect new or better information as it became available. In addition, updates to the analyses used to estimate historical production capacity have resulted in changes in the assignment of some populations to a historical size category.

The biological viability criteria described in this report are developed to inform long-term regional recovery planning efforts and delisting criteria. Given that intent, we worked to express the criteria in objective, measurable metrics. This provides a level of transparency that facilitates critical review and future refinements. In addition, the criteria we used to express viability facilitate the development of effective recovery strategies by focusing attention on specific, often spatially explicit, biological conditions or processes. For example, our criteria include quantitative metrics expressed in terms of the current distribution of spawners relative to spatially explicit maps of historical production potential within a population. We provide examples of the relative risk associated with a range of general spawning area configurations. The descriptions of risk associated with alternative configurations provide recovery planners with an objective basis for targeting actions to address that component of viability. Our abundance and productivity criteria were designed to be used, in combination with current assessments, to inform recovery planning efforts as to the relative magnitude of changes in survival and habitat capacity needed to achieve viable status. They can also provide insight into whether productivity alone, or both productivity and capacity might need to be improved. We provide population specific estimates of the relative improvements in productivity and abundance required based on current assessments in a separate report (ICTRT, 2006).

We discuss some of the key uncertainties and their implications relative to viability criteria in this report and provide guidance for addressing uncertainty. This will allow both scientists and policy-makers to include this uncertainty as they consider these criteria. For example, we provide options for directly including sampling uncertainty into estimates of current abundance and productivity parameters. For some populations, additional data or analyses may provide results that can improve current status assessments. We included some guidance for considering additional analyses in assessing status in terms of particular viability metrics (e.g., estimating population level productivity). Where alternative data or analyses are used for comparison, a clear rationale should be provided.

The biological viability criteria described in this document lay out population, MPG and ESU-level characteristics that, given currently available information, would be associated with persistence of salmonid ESUs for the foreseeable future. Two groups of TRT products will be forthcoming that rely heavily on these criteria. First, we are currently conducting this type of current status assessment for all populations in the Interior Columbia, and intend to compile the assessments in a salmon and steelhead "atlas." Drafts are available on our website: http://www.nwfsc.noaa.gov/trt/trt_current_status_assessments.cfm.

Second, we are conducting life-cycle modeling to assess the likely impact of different climate and hydropower scenarios on population status with respect to these criteria. Preliminary reports are also available on our website: http://www.nwfsc.noaa.gov/trt/trt_ic_viability_survival.cfm.

We have included two population viability assessments, Wenatchee River Spring Chinook Salmon and Umatilla River Summer Steelhead, as attachments to this document to serve as

examples of applying our population level viability criteria. These examples illustrate how current risk ratings for individual metrics can be estimated using the guidance provided in this report. In addition, these examples illustrate how to integrate across the metric level assessments to generate an overall risk rating for a particular population. The population-level assessments provide the basis for evaluating viability at the next hierarchical level, the MPG. For MPGs with several populations, there typically are several scenarios or combinations of populations that would satisfy our MPG-level viability criteria. Those scenarios are described in Appendix G. For example, the John Day River MPG is one of four MPGs in the Mid-Columbia Steelhead ESU. This MPG consists of five populations. Applying the MPG-level viability criteria related to population size described in this report, the John Day River MPG could be rated at viable status if the Lower Mainstem John Day River, North Fork John Day River, and either Middle Fork John Day River or Upper Mainstem John Day River populations meet the criteria for a viable population. In addition, the remaining two populations in the MPG would need to be rated as maintained using the guidance provided in this report. Based on the draft population status reviews, the North Fork population is rated Highly Viable but none of the other populations in the MPG satisfy the criteria for a viable population. Therefore, this MPG does not currently meet viability criteria. The John Day and the other three MPGs would need to meet viability criteria for the Mid-Columbia Steelhead ESU to be rated as viable. The scenarios or combinations of populations that would be consistent with our MPG and ESU-level criteria for all ESUs are explicitly described in Attachment 2.

The ICTRT viability criteria describe biological characteristics for an ESU, MPG, and component populations consistent with a high probability of long-term persistence. The criteria were designed so that an ESU would be able to survive adverse fluctuations from average environmental conditions while maintaining long-term adaptive potential, given our current understanding of population and metapopulation processes. The TRT viability criteria metrics are expressed as specific values that can inform setting quantitative biological objectives for long-term recovery planning. The metrics, in combination with limiting factors assessments, can be used in targeting and sizing recovery planning strategies on factors that have a high potential for improving the status of the component populations of ESUs. The criteria can also be directly applied or readily adapted to assess the potential risk implications of proposed implementation strategies.

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